

Taylor Reed Homes Limited

Main Street

Bettisfield

Hydraulic Modelling Report

January 2020

Project Information	
Project:	Main Street, Bettisfield
Report Title:	Hydraulic Modelling Report
Client:	Taylor Reed Homes Limited
Instruction:	The instruction to undertake this report was received from Mr. Gurjit Mahal on behalf of the Client.
File Ref:	12296-200130-HMR

Approval Record	
Authors:	Dr. Sandeep Bomminayuni PhD
Checker:	Rory Clements BSc (Hons) / David Hughes MEng (Hons)
Approver:	Alun Roberts BEng (Hons) CEng MICE

Document History	
Date	Comment
30/01/2020	First issue

Form Ref:

w042-F-57.5-F-Report-HMR-1D2D New Model EXG only

Contents

Introduction..... 1

Hydraulic Modelling..... 3

Results & Conclusions..... 8

Recommendations..... 11

Appendices

Appendix A Location Plan, Aerial Image and Photographs

Appendix B Survey Data

Appendix C Proposed Development Plans

Appendix D NRW Flood Maps

Appendix E Hydrology

Appendix F 2D Model Extents

Appendix G NRW Email correspondence

Appendix H Flood Mapping

Appendix I 2D Model Results Data

Tables

Table 1 - Primary Simulation Summary 3

Table 2 – Surveyed Structure Details 4

Table 3 - 2D Model Manning’s n Roughness Coefficients 5

Introduction

Waterco has been commissioned to undertake a detailed hydraulic modelling study of an unnamed watercourse (referred to as Bettisfield Brook hereon), which flows adjacent to a proposed development at Bettisfield, Whitchurch, Wales, SY13 2LN.

The outputs of the hydraulic modelling study provide a detailed, up-to-date assessment of the existing fluvial and pluvial flood risk at the site and quantify the change in flood risk elsewhere as a result of the development (if any).

A location plan and an aerial photograph of the site are included in Appendix A. The National Grid Reference (NGR) of the site is 346030 335360.

Site Description and Proposed Development

The site is currently entirely 'greenfield'. It is bordered by Cadney Lane to the east, open fields to the south and residential developments to the north, west and south-east of the site. Bettisfield Brook flows in a southerly direction adjacent to the eastern boundary of the site. Shropshire Union Canal flows at approximately 50 to 150m near the eastern and northern site boundary. The site covers an area of approximately 1.12ha.

A topographical survey of the site was undertaken by Jim Wright Surveying in March 2019 and is provided in Appendix B for information. The survey shows existing site levels fall west to north-east, from a level of approximately 87.87m AOD in the western corner to 85.37m AOD in the east. In general, the surveyed ground levels across the majority of the site are up to 1.5m below LiDAR levels off-site.

The proposed development plans are yet to be finalised and will be based on the outputs of the hydraulic modelling study. A concept development layout with a raised development platform and associated land lowering on site has been tested. To ensure the proposed development platform is flood-free during all fluvial and pluvial events, the platform will be entirely removed from the floodplain, as discussed further below. To mitigate flood risk on site and elsewhere arising as a result of the development (if any), the concept development plans also include:

- Land lowering which comprises removal of the existing high-level mounds at the northern half of the site (NGR 346025 335400) and setting the elevations to nearby ground levels to provide flood storage on site.
- A flood relief box culvert of 1.0m width and 0.5m height under the proposed platform (NGR 346028 335348).
- A small ditch along the southern site boundary immediately adjacent to the proposed development platform (NGR 346020 335340 to NGR 346113 335307) to convey flood flows around the development platform.

Levels elsewhere on site will remain unchanged from existing. A concept development plan is included in Appendix C for information.

Nearby Watercourses and Existing Flood Risk Data

The site is situated on the right bank of Bettisfield Brook. The watercourse flows in a southerly direction past the site at this location.

Flooding at the site could occur if water levels in Bettisfield Brook are sufficient to overtop local banks during, or following, an extreme fluvial event. The site is also at risk of pluvial or surface water flooding during rainfall events due to the relatively low-lying and flat site topography. Photographs of the site (Appendix A) obtained during March 2019 survey show standing water on the site. Both fluvial and pluvial flooding are considered the primary sources of flood risk at the site and are the main focus of this study.

Tidal flood risk has not been considered during this study given the site's relative elevation (> 85m AOD) and distance from the coast (~50km).

Wrexham County Borough Council (WCBC) Flood Risk Management Plan 2016 – 2021 report indicates that cases of Shropshire canal breach/overtopping were observed in the village of Bettisfield. It was reported that in 2004 and 2009 badgers burrowing under the canal caused flooding of fields and one property evacuation in the village of Bettisfield. However, no historical records of flooding are reported at the site within this report. NRW historical flood maps also show no past records of flooding at the site.

The current NRW Surface Water Flood Risk Maps (January 2020) show half of the site to be located within High Risk – an area considered to be at relatively high risk of pluvial flooding with an annual probability of the flooding greater than 3.3% (1 in 30) AEP (annual exceedance probability). Some portions of the site are located within Medium Risk – an area considered to be at medium risk of pluvial flooding with an annual probability of the flooding between 3.3% (1 in 30) AEP and 1% (1 in 100) and Low Risk - an area considered to be at low risk of pluvial flooding with an annual probability of the flooding between 1% (1 in 100) AEP and 0.1% (1 in 1000). An extract of the current NRW Surface Water Flood Risk Map is included in Appendix C for reference.

The NRW do not currently hold detailed fluvial flood risk maps or hydraulic model of the area. To provide a site-specific assessment of combined fluvial flood risk from Bettisfield Brook and pluvial flood risk, a 2-Dimensional (2D)¹ hydraulic model has been constructed. Such a model is considered the most appropriate model type in this instance given the requirement for detailed surface water flow route definition throughout the area. In addition to providing a more accurate assessment of existing fluvial flood risk at the site, the change in flood risk elsewhere (if any) arising as a result of the proposed development has also been quantified.

¹ 2-Dimensional (2D) Digital Terrain Model (DTM) of the potential floodplain, typically created from LiDAR data, supplemented with site specific topographical survey.

Hydraulic Modelling

This section provides details of the 2D hydraulic model build and the simulations and scenarios completed as part of this study.

Following an initial assessment of the existing fluvial and pluvial flood risk at the development site, simulation outputs will be compared against those generated using the proposed development layout to quantify the change in flood risk elsewhere as a result of the development (if any).

The latest version of TUFLOW hydraulic modelling software, 2018-03-AD, available at the start of the project has been used for all simulations.

Events considered

To fully investigate the fluvial flood risk from Bettisfield Brook and pluvial flood risk from rainfall events at the site, a range of both fluvial and pluvial events have been simulated; namely the 5% (Q20), 3.3% (Q30), 1% (Q100) and 0.1% (Q1000) AEP events. The impact of future climate change (CC) has also been investigated during the 1% AEP event by increasing flows and rainfall intensity by 25% (Q100CC1) and 70% (Q100CC2). (Site located in Severn River Basin; development considered 'More Vulnerable' with predicted 100-year lifetime – 'Central estimate' and 'Upper End estimate' allowance categories chosen). A list of simulations completed is given in Table 1.

To provide the required model inflows including hydrographs and hyetographs for fluvial and pluvial events respectively, a detailed hydrological assessment has been completed in accordance with the Flood Estimation Handbook (FEH), the EA Guidelines on use of FEH, namely 'Flood Estimation Guidelines, Technical guidance 197_08, v6 (2017)' and the NRW Guidance Note namely 'Flood Estimation: technical guidance. Reference Number GN008'. Both the FEH Statistical (peak flows only) and ReFH2.2 (peak flow, hydrograph shape and hyetographs) flow estimation methods have been used.

The completed hydrological calculations, summarised in a Flood Estimation Calculation (FEC) Record, are included in Appendix E, along with the final design hydrographs and hyetographs used. Peak fluvial flows and peak rainfall intensity estimates are given in Table 1.

Table 1 - Primary Simulation Summary

Fluvial Event (AEP)	Fluvial - Peak Flows (m ³ /s)	Pluvial - Peak Rainfall (mm/ts*)	Development Scenario
5%	0.52	2.87	Existing Site Layout (EXG) & Proposed Site Layout (DEV)
3.3%	0.57	3.26	
1%	0.76	4.61	
1% + 25% CC	0.95	5.76	
1% + 70% CC	1.29	7.83	
0.1%	1.28	7.85	

*Peak net rainfall values are mm per timestep (ts), which is 0.25 hours (15 minutes)

2D Model Details

The 2D TUFLOW model has been constructed from 1m LiDAR data, site-specific topographical and channel cross-section survey data (Appendix B). A review of the topographical survey has been carried out and all site levels have been extracted and input into the model using a triangulated irregular network (TIN).

The 2D model domain includes a representation of Bettisfield Brook starting from NGR 346180 335655 up to NGR 346510 334960 and covers a total area of 1.23km², both north and south of Shropshire Union Canal. The model domain north of the canal includes fluvial floodplain areas local to Bettisfield Brook, whereas, south of the canal the model domain includes significantly larger floodplain areas to capture surface water flows reaching the site. The 2D model extent is provided in Appendix F .

The 2D cell size has been set at 2m. This resolution is adequate to represent the flow paths on site and within the wider floodplain whilst maintaining a reasonable run time.

Bettisfield Brook cross-section survey data (Appendix B) has been used to represent the watercourse in the 2D domain. A TUFLOW z-shape layer has been utilised to represent and specify the cross-sectional width of the channel (generally varies between 2-4m) via the 'Shape Width' attribute. A z-shape layer has been used to stamp the surveyed bed levels at each cross-section into the 2D domain.

All hydraulically significant structures along the surveyed watercourse have been included in the model using ESTRY, the 1D component of TUFLOW. A total of six culverts have been surveyed and all have been included in the model as circular culverts. Table 2 provides details of these structures. A review of the remaining model extent has been carried out using aerial mapping (Google Maps) and it was found that there are no hydraulically significant structures present within the remaining floodplain.

Table 2 – Surveyed Structure Details

Model node ref.	NGR		Face Diameter (mm)		Length (m)	Blockage (%)
	Eastings	Northings	Upstream	Downstream		
Culv_1.03	346045	335530	550	550	29.0	0.0
Culv_1.06	346015	335475	300	300	11.5	0.0
Culv_1.07	346021	335468	100	100	11.5	0.0
Culv_1.10	346085	335405	700	700	7.0	16.5
Culv_1.11	346080	335400	600	600	7.0	23.5
Culv_1.16	346160	335340	500	500	120.0	84.4
Culv_1.19	346245	335165	450	450	4.0	90.7
Culv_1.22	346270	335130	500	500	206.5	0.0

As ESTRY does not allow representation of culverts with varying upstream and downstream face diameters (*Culv_1.06/1.07* and *Culv_1.10/1.11* in Table 2), the transition between upstream and downstream diameter is assumed to occur at half of the culvert length. The first half length of the culvert is represented as a circular culvert with diameter same as the upstream face surveyed diameter and the second half length is represented as a circular culvert with diameter same as the downstream face surveyed diameter.

Four out of the six surveyed culvert structures (*Culv_1.10*, *Culv_1.11*, *Culv_1.16* and *Culv_1.19* in Table 2)

were found to have been partially blocked with silt/debris at the entrance and exit of the culverts. Photographs of these structures are included in Appendix A for information. As per NRW's suggestion (email correspondence in Appendix F), the culverts have been represented as partially blocked in the EXG scenario model to mimic the survey observations. The percentage of cross-sectional area blocked has been computed using surveyed silt/debris levels and applied using the 'pBlockage' attribute of 1d_nwk table in ESTRY. A sensitivity test has been carried out to assess the impact on flood risk in the scenario where there is zero blockage of culvert due to removal of silt/debris and proper maintenance of watercourse channels, and is discussed further below.

During the March 2019 survey (Appendix B) standing water was observed on the site. The surveyed water levels have been utilised to specify initial water levels on the site to accurately represent the existing hydrological conditions on the site.

Fluvial inflows have been applied at the Bettisfield brook inflow location (NGR 346180 335655) north of Shropshire Union Canal using a source time (ST) boundary condition. Rainfall is applied as a distributed source in the model domain south of the canal using a rainfall (RF) boundary condition. The calculated inflow hydrographs and rainfall hyetographs presented in Appendix E have been specified as required.

2D open boundaries have been setup along the southern and eastern boundaries of the model (NGRs 346845 335220, 346610 335020, 346550 334985, 346510 334960, 346630 334725, 346385 334565, 345760 334540 and 345445 334785) using discharge-stage (QH or Rating Curve) boundary condition to prevent glass-walling. The QH relationship data has been automatically calculated by TUFLOW at the boundary location using an appreciation of the local ground slope (assessed using LiDAR). Sensitivity testing on this parameter has been performed to verify and is discussed below.

OS MasterMap data has been used to classify land use and assign Manning's n roughness coefficients throughout the floodplain. The coefficients used are given in Table 3.

Table 3 - 2D Model Manning's n Roughness Coefficients

Land Use	Manning's n Roughness Coefficient ($s/m^{1/3}$)
General surface	0.035
Buildings	0.500
Land	0.035
Inland water	0.030 – 0.035
Overgrown vegetation	0.060
Roads and tracks	0.022
Structures	0.025

To simulate and compare the concept development (DEV) arrangement to the existing flood levels, an alternative DEV scenario has been created (Appendix C). The following updates have been made to the existing 2D model to create the DEV scenario:

- The proposed development platform has been removed from the floodplain by deactivating a portion of the model domain to ensure it does not flood.
- TUFLOW z-shapes have been used to represent the proposed land lowering on the northern half of the site.
- The proposed flood relief culvert under the development platform has been represented in the model using ESTRY, 1D component of TUFLOW. A 1d_nwk line with an 'R' type and dimensions set to 1.0m width and 0.5m height has been utilised to model the proposed culvert.
- TUFLOW z-shape features have been used to represent the proposed ditch along the southern site boundary adjacent to the development platform. The proposed ground levels along the ditch vary from 85.91 m AOD to 85.43 m AOD at the north-western corner to south-eastern corner of the development platform respectively.
- To model future drainage flows from the development, a point outfall located at the north-eastern corner of the development platform has been included in the DEV model. A constant flow of 2l/s has been assumed to be discharged into Bettisfield Brook and represented in the model using a QT boundary condition.

Areas not covered by the proposed level data have been represented using existing levels.

Sensitivity Testing

NRW historical flood maps (Appendix C) have been used to compare model outputs as discussed in the results section below.

In the absence of available calibration data, increased significance has been placed on sensitivity testing to improve confidence in the model outputs and assess the sensitivity of the model parameters. Seven sensitivity tests have been carried out (ST1-7) with respect to the 1% AEP + CC1 fluvial and pluvial event.

Sensitivity tests "ST1" and "ST2" investigate variation (+/- 20%) of Manning's roughness coefficients in both the Bettisfield Brook channel structures and across the floodplain.

Sensitivity tests "ST3" and "ST4" investigate a +/-20% variation in the slope used to calculate the QH curve of the downstream boundary conditions of 2D model.

Sensitivity tests "ST5" and "ST6" investigate a +/-20% variation in the watercourse inflows and rainfall applied to the 2D model.

As suggested by NRW (email correspondence in Appendix F), a sensitivity test "ST7" investigating a 'no

blockage' scenario for all the existing culverts in the model has been setup. The aim of "ST7" simulation is to investigate the impact on flood risk at the site in the scenario where periodic maintenance of watercourse channels would ensure removal of silt/debris at culvert entrance and exit locations. To model this scenario, the "pBlockage" attribute of all culverts has been set to zero and channel bed levels at cross-sections in the vicinity of the culverts have been lowered by appropriate values which were calculated as the difference between surveyed channel bed level and culvert invert level data.

Results & Conclusions

This section of the report documents the results obtained from the primary simulations, both EXG and DEV, and sensitivity tests.

Maximum flood depth mapping has been provided for each primary simulation in Appendix H. **Error! Reference source not found..**

Maximum water level data has been extracted at selected node locations across the site in the 2D domain, and represented in Appendix H.

Detailed below is a summary of the flood mechanisms for the simulated events, which is to be read in conjunction with the above detailed information.

EXG Simulations - Existing Site Layout

During each simulated flood event the results of the modelling highlight complex flooding mechanisms and surface water flow paths through the entire site. The flooding mechanisms on the site are discussed in detail below.

The majority of the surface water flow reaching the site originates from the surrounding area which is elevated high ground (relative to the site) at two key locations: A) open fields to the south of Knowles Lane (approximate NGR 345610 335150) and B) open fields to the east of Cadney Lane (approximate NGR 346380 335410). Surface water flow from location A follows topographical low points and generally flows in a north-easterly direction over Knowles Lane and enters the site via the western site boundary (approximately from NGR 345970 335390 to 346000 335330). Surface water flow from location B flows in a south-westerly direction and overtops Cadney Lane before entering the site via the southern and eastern site boundaries (approximately from NGR 346050 335360 to 346110 335300). From here floodwater flows in a north-west direction through the southern half of the site and joins the floodwater from Location A before continuing to flow in a north-easterly direction through the northern half of the site. The floodwater causes inundation of the entire site before flowing into Bettisfield Brook channel adjacent to the eastern boundary of the site.

After the surface water flooding begins to recede, fluvial flows in Bettisfield Brook causes floodwater to enter the site via the northern site boundary. Out-of-bank flooding on the right bank of the watercourse causes floodwater to flow in a south-western direction through the northern half of the site. From here floodwater joins the surface water flow from Location A near the western site boundary before continuing to flow in a south-eastern direction through the southern half of the site and ultimately out of the site near the southern site boundary (NGR 346110 335300).

DEV Simulations - Post-Development Site Layout

Model outputs from the DEV simulations show that the proposed development platform is completely flood-free during all the simulated events as the platform has been removed out of the floodplain.

The flooding mechanisms on the site during the DEV scenario are similar to the EXG scenario. The surface water flow from Location A indicated above enters the site via the western site boundary and continues to

flow in a north-eastern direction through the northern half of the site. The floodwater from Location B enters the site via the eastern site boundary and flows in a north-west direction through the southern half of the site and joins the floodwater from Location A before continuing to flow in a north-easterly direction through the northern half of the site. The proposed development platform causes some of the floodwater from Location B to enter the proposed ditch at the south-eastern corner of the site and flow in a north-western direction along the proposed development platform edge. From here the floodwater joins some of surface water flow from Location A and flows under the development platform via the proposed flood relief culvert.

Similar to the EXG scenario, after the surface water flooding begins to recede, out-of-bank fluvial flooding in Bettisfield Brook causes floodwater to enter the site via the northern site boundary. This floodwater joins surface water flow from Location A and flows in a south-eastern direction through the site and ultimately out of the site near the southern site boundary (NGR 346090 335330).

Flood Risk Elsewhere

The potential impact of the proposed development on flood risk elsewhere has been quantified by comparing the results of the existing (EXG) site layout simulations with the proposed (DEV). To provide a detailed assessment of the relative changes in flood depths throughout the floodplain, a series of depth difference maps comparing the EXG and DEV maximum depths have been created and are included in Appendix H.

The DEV versus EXG flood depth difference maps for all the simulated events show the proposed development platform generally has a negligible impact on flood depths ($\pm 5\text{mm}$) off-site. For all the simulated events, increases in maximum flood depths on site indicate that concept compensatory storage is working as intended. A local increase in flood depths is observed on the access road at the western site boundary (NGR 345995 335355) immediately adjacent to the proposed development platform during all events including and up to the 1% AEP + 25%CC event. This increase is caused due to the local build-up of floodwater as a result of the raised development platform being located immediately adjacent to the access road within the concept development layout modelled in this study. Land grading from the access road towards the raised development platform area is recommended to be included in the final development layout to remove this minor off-site increase in flood risk.

Model Verification and Sensitivity Tests

Comparison of model results against historical flood maps was not possible as there are no available maps, flood extents or gauge data of past historical flooding at the site.

The results of sensitivity tests ST1 and ST2 show that a significant variation ($\pm 20\%$) in the Manning's 'n' coefficients used within the channel and floodplain does not increase/decrease the maximum water levels on site and throughout the model by more than 25mm.

The results of sensitivity tests ST3 and ST4 show that significantly varying the slope value used at the downstream boundary by $\pm 20\%$ does not have any effect on the maximum water levels at the site – any minor variation is local to the boundary only. The assessment of flood risk at the site remains unaffected.

The results of sensitivity tests ST5 and ST6 show that significantly varying the fluvial inflow and pluvial rainfall

by +/-20% respectively causes an increase/decrease in maximum water levels and flood extents throughout the model as can be expected. The flood depths across the site increase by up to 90mm during ST5 scenario (increasing the inflow hydrograph and rainfall by 20%) and decrease by up to 180mm during ST6 scenario (decreasing the inflow hydrograph by -20%).

The results of sensitivity tests ST7 show that clearing the channel and structures of silt and debris causes a local increase in the in-channel maximum flood depths by up to 40mm. However the assessment of flood risk at the site remains unaffected with negligible changes in maximum flood depths on site.

Recommendations

The hydraulic model and associated report should be submitted to the NRW for review and approval as a reasonable representation of the fluvial and pluvial flood risk at the existing and the proposed site.

The outputs of this modelling study should be used to inform the site layout design and support the Flood Consequences Assessment. The proposed level information modelled as part of this report (DEV) provide proof of concept only. They do not constitute detailed design. Prior to any construction, detailed design of a proposed site layout is recommended with any changes to the final layout modelled to ensure the final proposed scheme performs as intended, reducing risk to the development without increasing risk to the surrounding area.

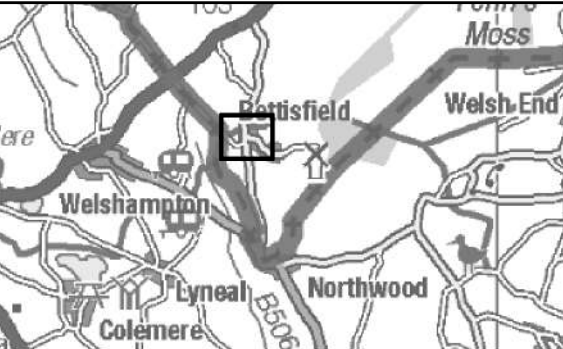
Appendix A Location Plan, Aerial Image and Photographs



NOTES:
1) ALL DIMENSIONS ARE IN METRES AND ALL LEVELS IN METRES ABOVE ORDNANCE DATUM UNLESS STATED OTHERWISE

LEGEND

Site Boundary



CLIENT:

TAYLOR REED HOMES LTD



www.waterco.co.uk

SCHEME:

**MAIN STREET,
BETTISFIELD**

PLOT TITLE:

AERIAL PLAN

PLOT STATUS:

FINAL

DATE:

23/01/2020

DRAWN:

VJ

CHECKED:

DH

APPROVED:

AR

PLOT SCALE @ A3:

1:2,500

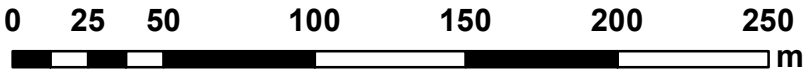
(UNLESS STATED OTHERWISE)

PLOT NAME:

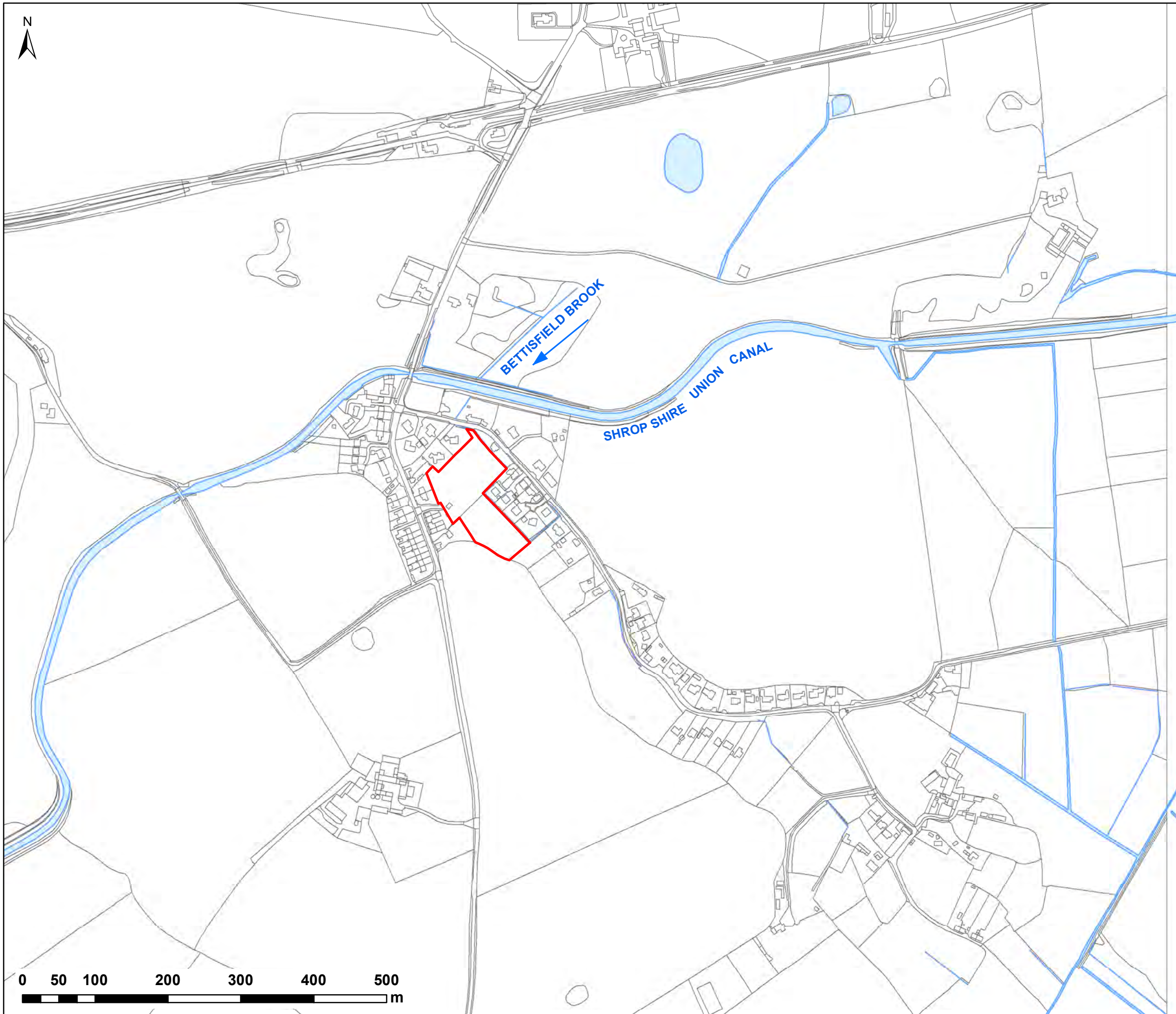
12296-Aerial_Plan

REV:

-



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



NOTES:
1) ALL DIMENSIONS ARE IN METRES AND ALL LEVELS IN METRES ABOVE ORDNANCE DATUM UNLESS STATED OTHERWISE

LEGEND

Site Boundary

Watercourses / Water Bodies

CLIENT:

TAYLOR REED HOMES LTD

www.waterco.co.uk

SCHEME:

**MAIN STREET,
BETTISFIELD**

PLOT TITLE:

LOCATION PLAN

PLOT STATUS:			DATE:
FINAL			29/01/2020

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
VJ	DH	AR	1:5,000
			(UNLESS STATED OTHERWISE)

PLOT NAME:	REV:
12296-Location_Plan	-

Photographs from March 2019 survey showing standing water on the site:



Photograph of the upstream face of blocked Culvert structure Culv_1.10 (NGR 346085 335405):



Photograph of the upstream face of blocked Culvert structure Culv_1.16 (NGR 346160 335340):



Photograph of the downstream face of blocked Culvert structure Culv_1.19 (NGR 346245 335165):



Appendix B Survey Data

- Notes:
- 1 All dimensions in millimetres and all levels in metres AOD unless shown otherwise
 - 2 Surveyed using Trimble 5700 GPS and 5600 total station
 - 3 Co-ords and levels OSGM15 and OSTN15

KEY

REFERENCES

A	28/03/19	Original Survey
REV	Date	Description

CLIENT



JIM WRIGHT
SURVEYING

01939 260522 surveys@wrightsurv.plus.com

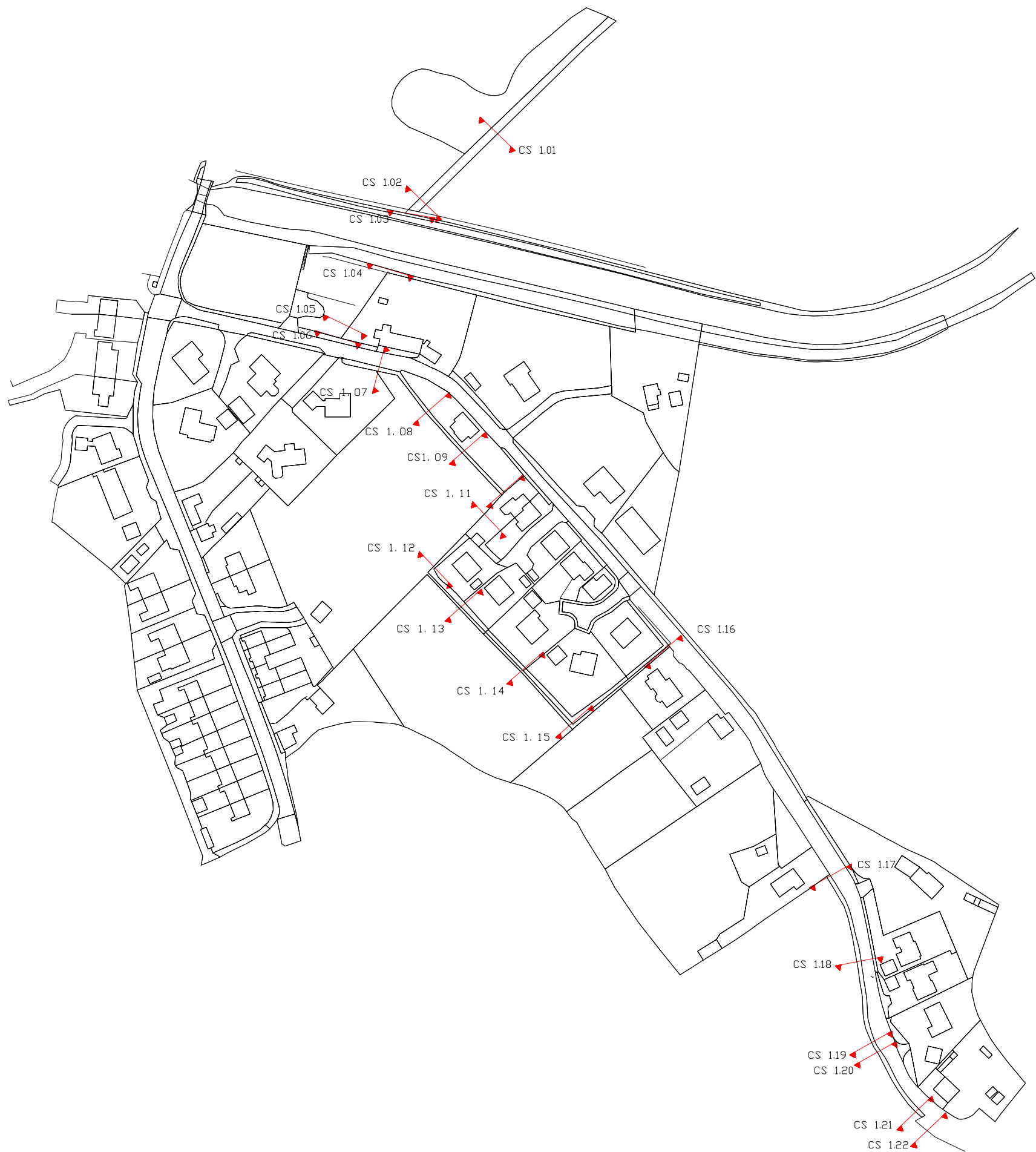
SCHEME

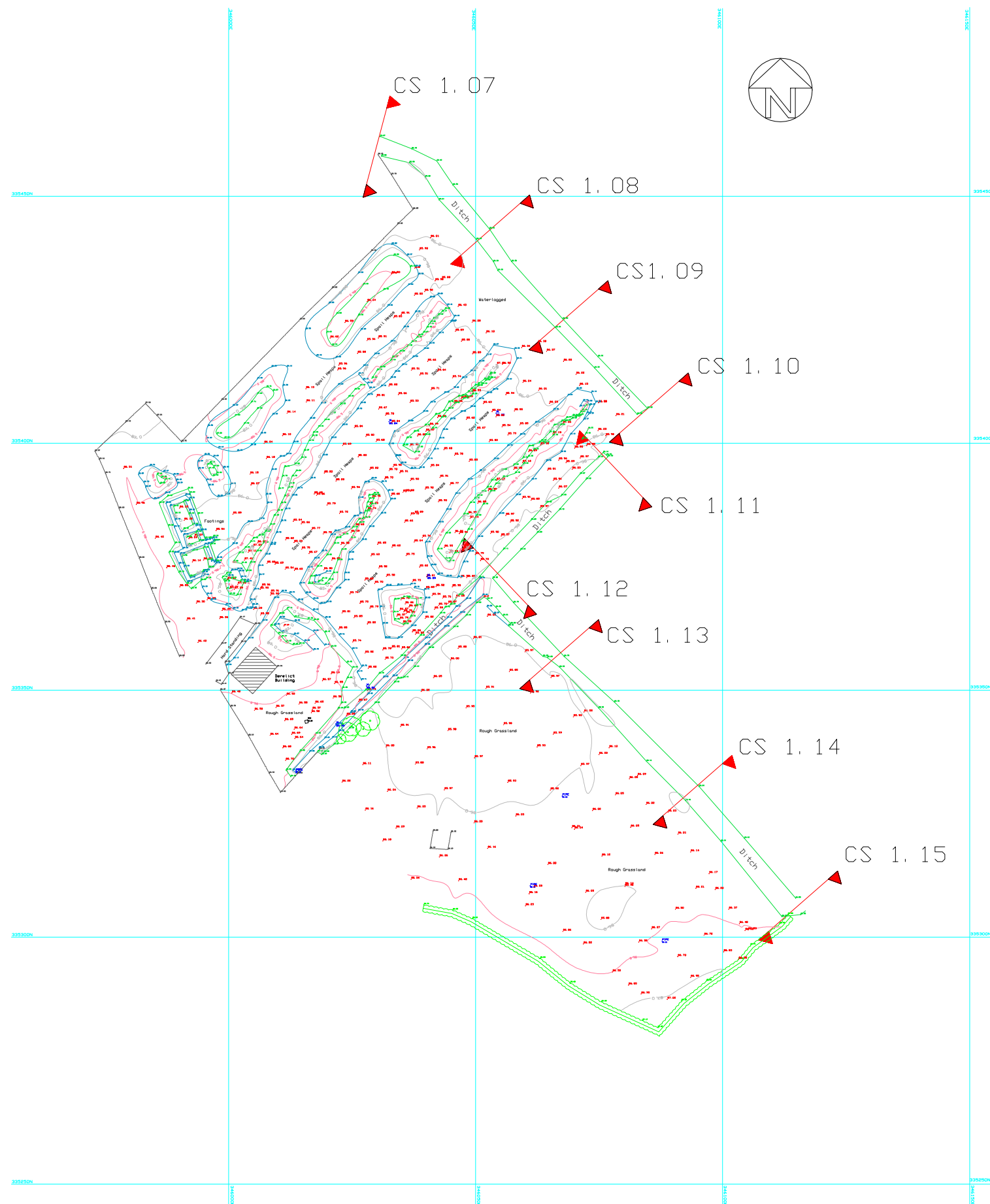
Main Street Bettisfield

TITLE

Ditch Section Positions on OS

STATUS			
DRAWN	CHECKED	APPROVED	SCALE
			1:1000 at A3
DRAWING NO.			REV
w3371_main street_bettisfield_sections_on_OS			





- Notes:
- 1 All dimensions in millimetres and all levels in metres AOD unless shown otherwise
 - 2 Surveyed using Trimble 5700 GPS and 5600 total station
 - 3 Co-ords and levels OSGM15 and OSTN15

Key

- Levels 85, 91
Bank Bottom
Bank Top
Building
Fence
Hedge
Cross Section

REFERENCES

A	28/03/19	Original Survey
REV	Date	Description

CLIENT

**JIM WRIGHT
SURVEYING**
01939 260522 surveys@wrightsurv.plus.com

SCHEME

Main Street Bettisfield

TITLE

Site Plan

STATUS

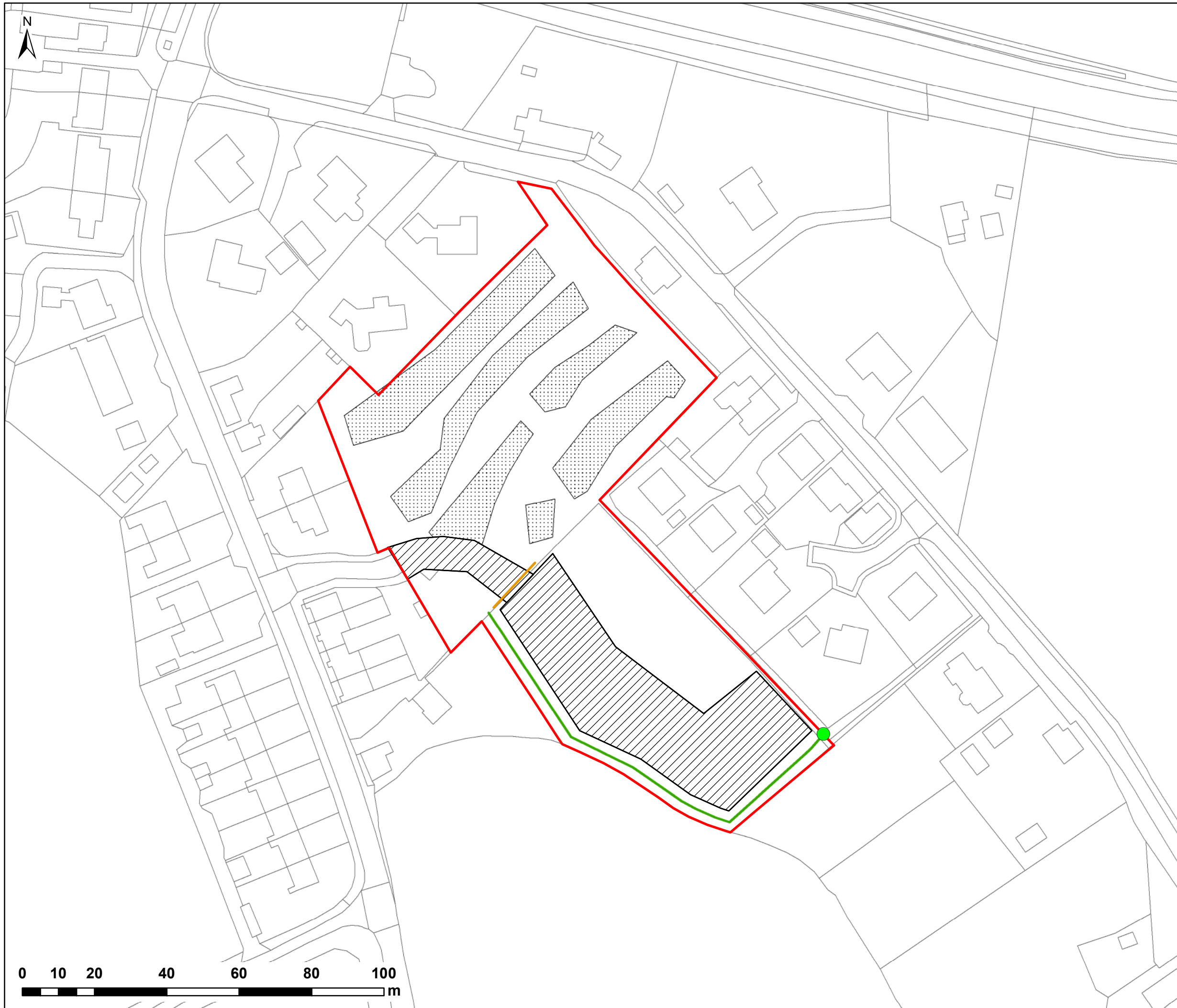
DRAWN	CHECKED	APPROVED	SCALE
			1:1000 at A3

DRAWING NO.	REV
w3371_bettisfield_main_street_site_plan	



DRAWING NO.	REV
w3371_main street_bettisfield_ditch_sections	

Appendix C Proposed Development Plans



NOTES:
1) ALL DIMENSIONS ARE IN METRES AND ALL LEVELS IN METRES ABOVE ORDNANCE DATUM UNLESS STATED OTHERWISE

LEGEND

- Site Boundary
- Proposed Platform
- Proposed Site Lowering
- Proposed Ditch
- Proposed Flood Relief Culvert
- Outfall Location

CLIENT:

TAYLOR REED HOMES LTD

www.waterco.co.uk

SCHEME:

**MAIN STREET,
BETTISFIELD**

PLOT TITLE:

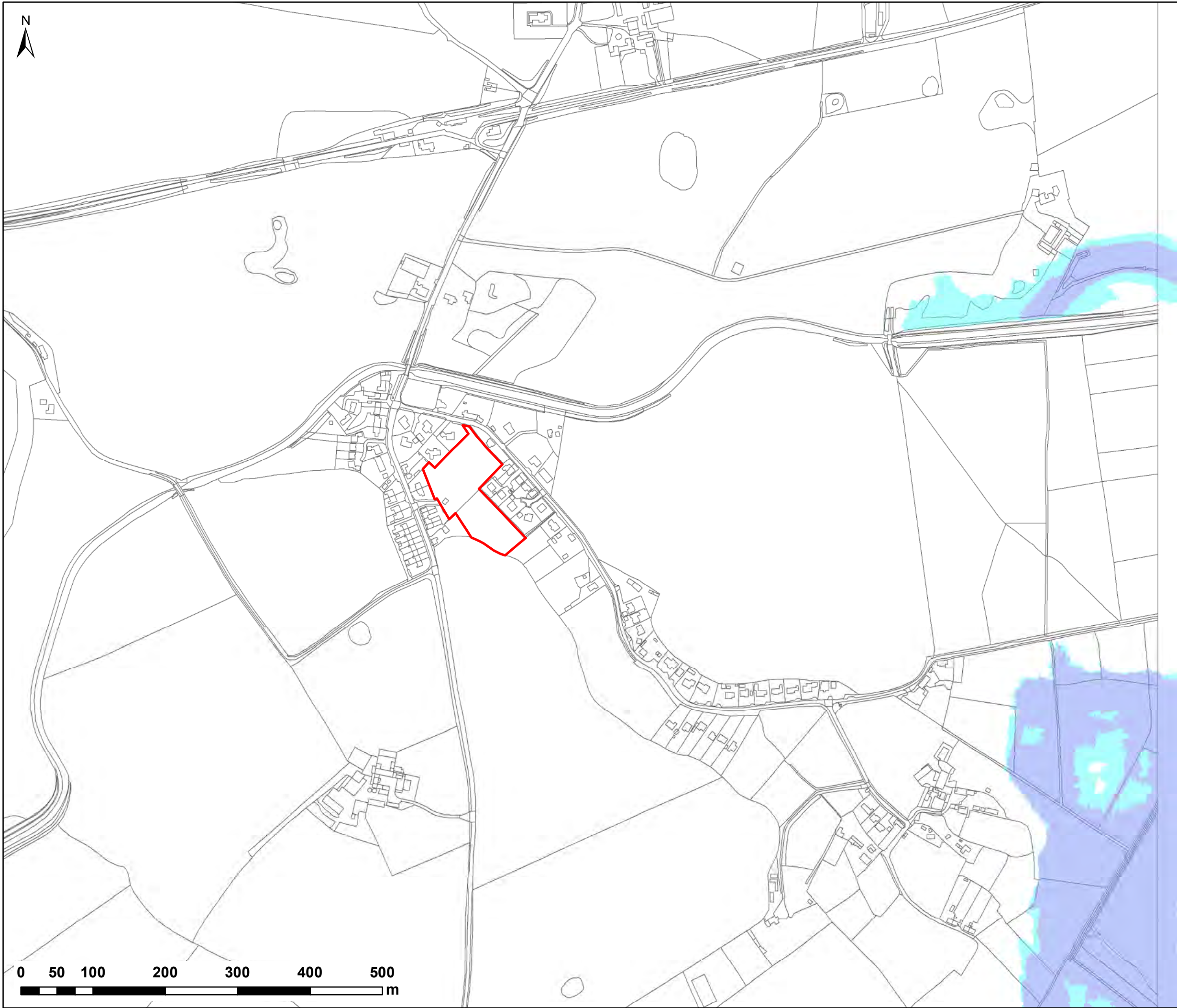
**CONCEPT
DEVELOPMENT LAYOUT**

PLOT STATUS:			DATE:
FINAL			29/01/2020

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
VJ	DH	AR	1:1,000 (UNLESS STATED OTHERWISE)

PLOT NAME:	REV:
12296-Concept_Dev_Layout	-

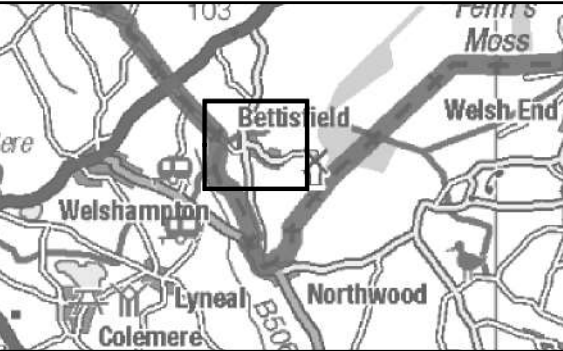
Appendix D NRW Flood Maps



NOTES:
1) ALL DIMENSIONS ARE IN METRES AND ALL LEVELS IN METRES ABOVE ORDNANCE DATUM UNLESS STATED OTHERWISE

LEGEND

-  Site Boundary
-  NRW Flood Zone 3
-  NRW Flood Zone 2



CLIENT:

TAYLOR REED HOMES LTD



www.waterco.co.uk

SCHEME:

**MAIN STREET,
BETTISFIELD**

PLOT TITLE:

NRW FLOOD MAP FOR PLANNING
DATA ACCESSED JANUARY 2020

PLOT STATUS:

FINAL

DATE:

29/01/2020

DRAWN:

VJ

CHECKED:

DH

APPROVED:

AR

PLOT SCALE @ A3:

1:5,000

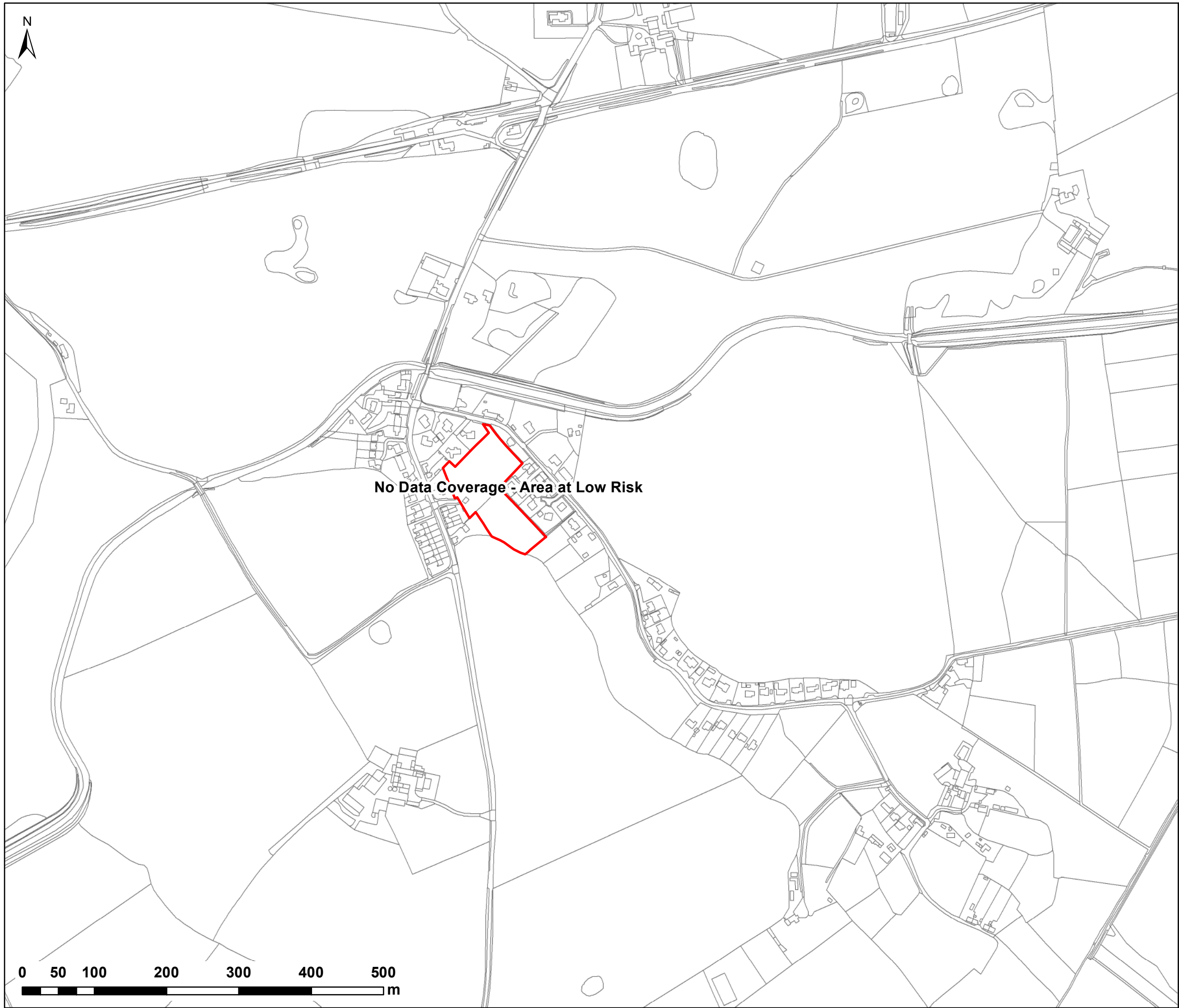
(UNLESS STATED OTHERWISE)

PLOT NAME:

12296-NRW_FZ_FM

REV:

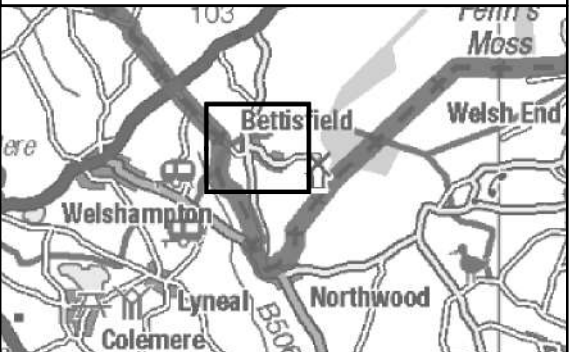
-



NOTES:
1) ALL DIMENSIONS ARE IN METRES AND ALL LEVELS IN METRES ABOVE ORDNANCE DATUM UNLESS STATED OTHERWISE

LEGEND

-  Site Boundary
-  Historical Flood Map



CLIENT:

TAYLOR REED HOMES LTD



www.waterco.co.uk

SCHEME:

**MAIN STREET,
BETTISFIELD**

PLOT TITLE:

NRW HISTORICAL FLOOD MAP
DATA ACCESSED JANUARY 2020

PLOT STATUS:

FINAL

DATE:

29/01/2020

DRAWN:

VJ

CHECKED:

DH

APPROVED:

AR

PLOT SCALE @ A3:

1:5,000

(UNLESS STATED OTHERWISE)

PLOT NAME:

12296-NRW_Hist

REV:

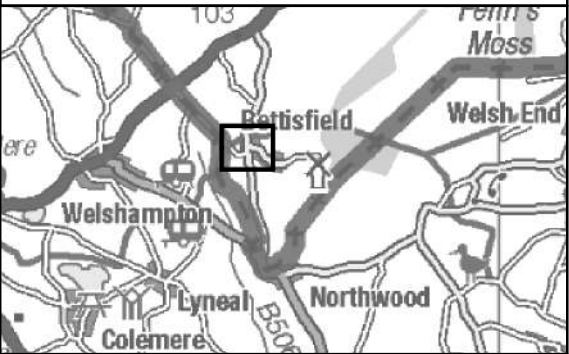
-



NOTES:
1) ALL DIMENSIONS ARE IN METRES AND ALL LEVELS IN METRES ABOVE ORDNANCE DATUM UNLESS STATED OTHERWISE

LEGEND

-  Site Boundary
-  High (3.3% or greater)
-  Medium (between 1.0% and 3.3%)
-  Low (between 0.1% and 1.0%)



CLIENT:

TAYLOR REED HOMES LTD



www.waterco.co.uk

SCHEME:

**MAIN STREET,
BETTISFIELD**

PLOT TITLE:

**NRW FLOOD RISK FROM
SURFACE WATER
JANUARY 2020**

PLOT STATUS:

FINAL

DATE:

29/01/2020

DRAWN:

VJ

CHECKED:

DH

APPROVED:

AR

PLOT SCALE @ A3:

1:2,500

(UNLESS STATED OTHERWISE)

PLOT NAME:

12296-NRW_SW

REV:

-

Appendix E Hydrology



Project: Main Street, Bettisfield

Date: 29/01/2020

Job No: w3371

Revision:

Prepared by: Manfredi Toraldo MEng MSc MCJWEM

Checked by: Adam Parkinson BSc (Hons)

Approved by: Rory Clements BSc (Hons)

Flood estimation calculation record

Introduction

This document is a supporting document to the Natural Resources Wales (NRW) Flood Estimation Technical Guidance Note (GN008). It provides a record of the calculations and decisions made during flood estimation. It will often be complemented by more general hydrological information given in a project report. The information given here should enable the work to be reproduced in the future.

Contents

1.	Method statement.....	3
2.	Locations where flood estimates are required	10
3.	Statistical method	13
4.	Revitalised flood hydrograph (ReFH) method	25
5.	Discussion and summary of results	27
6.	Annex – supporting information	32

Abbreviations

AM	Annual maximum
AREA	Catchment area (km ²)
BFI	Base flow index
BFIHOST	Base flow index derived using the HOST soil classification
DPLBAR	Mean drainage path length (km)
DPSBAR	Mean drainage path slope (m/km)
FARL	FEH index of flood attenuation due to reservoirs and lakes
FEH	Flood Estimation Handbook
FPEXT	Floodplain extent
FSR	Flood Studies Report
HOST	Hydrology of soil types
NRFA	National River Flow Archive
NRW	Natural Resources Wales
POT	Peaks over a threshold
QMED	Median annual flood (with return period 2 years)
ReFH	Revitalised flood hydrograph method – used for rainfall runoff method
SAAR	Standard average annual rainfall (mm)
SPR	Standard percentage run-off
SPRHOST	Standard percentage run-off derived using the HOST soil classification
Tp (0)	Time to peak of the instantaneous unit hydrograph
URBAN	Flood Studies Report index of fractional urban extent
URBEXT2000	Revised index of urban extent
WINFAP	Windows Frequency Analysis Package – used for FEH statistical method

1. Method statement

1.1. Overview of requirements for flood estimates

Item	Comments
Give an overview which includes: • purpose of study • approximate number of flood estimates required • peak flows or hydrographs • range of return periods and locations • approximate time available	The purpose of the study is to provide design hydrographs and hyetographs for the catchment of an unnamed watercourse (named “Cadney Lane Stream” for the purposes of this study) flowing adjacent to a proposed residential development site located between Cadney Lane and Northwood Road at Bettisfield, Wrexham, Wales, SY13 2LW [NGR 346040 335400]. Hydrographs and hyetographs are required for the 50% (Q2 and R2), 5% (Q20 and R20), 3.3% (Q30 and R30), 1% (Q100 and R30), 1%+CC1 (Q100+25% and R100+25%), 1%+CC2 (Q100+70% and R100+70%) and 0.1% (Q1000 and R1000) AEP events to be used as input data for a 2D fluvial/pluvial hydraulic model of the catchment. The scope of the model is to inform a Flood Consequence Assessment (FCA) for the development site.

1.2. Overview of catchment

Item	Comments
Brief description of catchment, or reference to section in accompanying report. Include maps where necessary.	Cadney Lane Stream upper catchment is located to the north of the village of Bettisfield; the watercourse crosses beneath the Shropshire Canal through a culvert (NGR 346040 335515) and flows through Bettisfield in a south-easterly direction, discharging to an unnamed tributary of the River Roden, approximately 1km downstream of the village. The study catchment is small (1.1km²), mostly flat (DPSBAR 52.9m/km) and essentially rural (URBEXT₂₀₀₀ = 0.021). The Shropshire Canal dissects the catchment providing two sub-catchments named “north sub-catchment” and “south sub-catchment” for this study. As stated above, the sub-catchments

	are connected via the culvert beneath the canal (drainage slope from north to south). A review of the 1:50,000 British Geological Survey (BGS) maps reveals that the whole catchment is underlain by the Sidmouth Mudstone formation, a sedimentary bedrock of fluvial, lacustrine and marine origin. Superficial deposits are present over the whole catchments and are represented by sedimentary deposits of glaciofluvial and glacial origin. The predominant soil types within the catchment are described as “slowly permeable seasonally wet slightly acid but base-rich loamy and clayey soils” and “freely draining slightly acid loamy soils” (source: http://www.landis.org.uk/soilscapes). The two soil types are therefore very different and identify two well defined infiltration behaviours, discussed further in section 1.8. Evidence of standing water is observed near to the subject site (see section 1.7). A location plan is provided in Annex 6.1
--	--

1.3. Source of flood peak data

Item	Comments
Was the NRFA Peak Flows dataset used? If so, which version? If not, why not? Record any changes made.	Yes – Version 7.0, October 2018 – latest dataset available at the start of the project.

1.4. Gauging stations (flow or level)

At the sites of flood estimates or nearby at potential donor sites. Also state gauging authority number where it is different to the NRFA number.

Water course	Station name	NRFA number (used in FEH)	Grid reference	Catchment area (km ²)	BFIHOST	FPEXT	URBEXT 2000
No available stations within the catchment boundary or in the vicinity.							

1.5. Data available at each flow gauging station

Station Name	Start and end date on NRFA	Update for this study?	Suitable for QMED?	Suitable for pooling?	Data quality check needed?	Other comments on station and flow quality e.g. information from NRFA Peak Flows, trends in flood peaks, outliers
N/a						

1.6. Rating equations

Station name	Type of rating e.g. theoretical, empirical, degree of extrapolation	Rating review needed?	Reasons e.g. availability of recent flow gaugings, amount of scatter in the rating
N/a			
Include a link or reference to any rating reviews carried out			

1.7. Other data available and how it has been obtained

Type of data	Data relevant to this study?	Data available?	Source of data and licence reference from NRW	Details
--------------	------------------------------	-----------------	---	---------

Check flow gaugings (if planned to review ratings)	N/a	No		
Historic flood data – give link to historic review if carried out			Email received from Neil Taunt of Wrexham County Borough Council on 08/01/2019	An email received from Neil Taunt of Wrexham County Borough Council (WCBC) states that “there are historic incidents of flooding of property in the locality, thought to be associated with the conveyance of surface waters”. However, the only recorded historic flood events revealed by an online search are related to breach/overtopping of the Shropshire Canal occurring around the village of Bettisfield (see the WCBC Flood Risk Management Plan 2016 – 2021, page 12, for more details). WCBC have provided photographs (included in Annex 6.1) which show standing water on site consistent with the topographic survey of the site (March 2019).
Flow data for events	N/a	No		
Rainfall data for events	N/a	No		
Results from previous studies	N/a	No		There are no existing hydrological studies which focus on this specific area.
Other data or information e.g. groundwater, tides	N/a	No		

1.8. Initial choice of approach

Item	Comment
Outline the conceptual model. Address questions such as: • Where are the main sites of interest? • What is likely to cause flooding at those locations? (e.g. peak flows, flood volumes, combination of peaks, groundwater, snowmelt, tides) • Might those locations flood from runoff generated on part of the catchment only e.g. downstream of a reservoir?	The proposed development site described in section 1.1 is the primary interest of this study. Flooding could occur if the local conveyance capacity of Cadney Lane Stream is exceeded or if the local surface water routes converge on the development site area. A mixed fluvial/pluvial 2D model will be built in order to assess both risks; a fluvial point inflow will be located upstream of the culvert under the Shropshire Canal (to include the fluvial flood risk from the north sub-catchment) and net rainfall hyetographs will be applied over the south sub-catchment area (to consider the local surface water flood risk). More information regarding the model build and methodologies are available in the Hydraulic Modelling Report (HMR), of which this FEC Record forms an Appendix.
Any unusual catchment features to take into account? e.g. • highly permeable (BFIHOST > 0.65) – consider permeable catchment adjustment for statistical method if SPRHOST < 20% • highly urbanised – consider choice of method carefully; consider method that can account for differing sewer and topographic catchments • pumped watercourse – consider lowland catchment version of rainfall-runoff method • major reservoir influence (FARL < 0.90) – consider flood routing • extensive floodplain storage – consider choice of method carefully	• FEH BFIHOST value of the catchment is an average 0.402. However, as two very different soil configurations are present in the catchment (see section 1.2), a Soil Site Report has been purchased from Cranfield University in order to further assess the BFIHOST value. Following review of the Soil Site Report the BFIHOST value was re-calculated to 0.383, a relatively good match to the FEH value, and confirmed that the catchment does not require permeable adjustment. More details on the BFIHOST calculations are given in section 2.3. • The urban area is minimal (URBEXT₂₀₀₀ = 0.0208) and the catchment is considered essentially rural. • There are no significant online ponds or reservoirs and the catchment FARL value is equal to 1. • Other Catchment Descriptors (CDs) are within standard limits. • The catchment is not believed to be pumped and does not show extensive floodplain storage (FPEXT=0.33). • The catchment has a minimum elevation of 86m AOD and is therefore not tidally influenced.

Initial choice of method(s) and reasons

- Are FEH statistical and/or ReFH appropriate?
- If not appropriate, describe why and give details of the other methods to be used.
- Will the catchment be split into sub-catchments/intervening areas? If so, how will flows for intervening areas be estimated?

As both hydrographs and hyetographs are required for the hydraulic model, two different procedures will be followed. A single analysis will be performed for the catchment as a whole using the FEH Statistical and the ReFH2 methods (both appropriate for the subject catchment); the results will be compared, and the most appropriate method will be selected for the design hydrographs. The resulting hydrographs will be scaled according to sub-catchment AREA (as per the table below) in order to provide the point inflows to be applied upstream of the Shropshire Union Canal (representing the contribution of the north sub-catchment; south sub-catchment data is reported in the table for information only).

Sub-catchment	Catchment Area (km ²)	Ratio (Sub-catchment/Total Catchment)
Full Catchment (S001)	1.107	-
North sub-catchment (NS)	0.848	0.766
South sub-catchment (SS)	0.259	0.234

The “net rainfall” hyetograph (i.e. which accounts for rainfall depth losses due to soil type and urbanisation parameters within the catchment) obtained through the ReFH2 method (as FEH Statistical only produces fluvial flows) will be then applied to the south sub-catchment in order to complete the required model inputs. The hyetographs do not need to be scaled as they are expressed as mm of rainfall per timestep (15min intervals); rainfall can therefore be applied to the equivalent area of the south sub-catchment.

This approach has been deemed the most accurate (using standard methodologies) considering the catchment peculiarities

	(catchment is bisected by a canal with hydrographs required for the North sub-catchment and hyetographs for the South sub-catchment).
Software to be used (with version numbers) edit or delete as applicable, or add others	WINFAP-FEH version 4. ReFH version 2.2 (ReFH2).

2. Locations where flood estimates are required

2.1. Summary of subject sites

The table below lists the locations of subject sites. Include site codes in all subsequent tables to save space.

Site code	Watercourse	Site	Easting	Northing	AREA on FEH Web Service (km ²)	Revised AREA if altered
S001	Cadney Lane Stream	Downstream of subject site	346150	335300	1.25	1.107
Reasons for choosing above locations	The catchment boundary was chosen to include all potential locations where overland flow could reach the subject site.					

2.2. Important catchment descriptors at each subject site (incorporating any changes made)

Site code	FARL	PROPWET	BFIHOST	DPLBAR (km)	DPSBAR (m/km)	SAAR (mm)	SPRHOST	URBEXT 2000	FPEXT
S001	1	0.34	0.383	0.8327	52.9	703	46.5	0.0208	0.33

2.3. Checking catchment descriptors

Item	Comment
Record how catchment boundary was checked - describe any changes - refer to maps if needed	The catchment boundary was checked through a watershed analysis in GIS software, utilising 1m NRW Light Detection and Ranging (LiDAR) terrain data. Discrepancies between the FEH boundary and the GIS watershed analysis boundary were identified. The GIS watershed analysis boundary has been preferred as it is based on a more accurate higher resolution terrain dataset. The area value has been updated and reduced from 1.25km² to 1.107km². A comparison between the FEH and the adopted catchment boundary has been included within Annex 6.2.

Record how other catchment descriptors were checked, especially soils

- describe any changes
- include a before and after table if necessary

CDs for the subject catchment have been purchased from the FEH Web Service and updated as described below.

BFIHOST – has been checked using Cranfield Soil mapping, BGS geology mapping and HOST maps purchased for the purpose of this assessment. A Hydrology of Soil Type (HOST) map has been purchased to re-calculate the BFIHOST value for the catchment based on the new area. A copy of the map is included in Annex 6.2. There are two HOST classes overlaying the catchment, Classes 5 and 24, which have BFIHOST values of 0.9 and 0.312 respectively, with the majority of the catchment (approximately 90%) within Class 24. The exact area weighting values are summarised in the following table.

HOST Class	BFIHOST Value	Area	Weighted area
5	0.9	0.133	0.120
24	0.312	0.974	0.880

The updated BFIHOST value for the whole catchment is equal to 0.383. As the permeable HOST class 5 soil is almost exclusively located in the south sub-catchment (see Annex 6.2), modifying the BFIHOST value in the ReFH2 calculations of the net hyetograph (to be applied on the South sub-catchment only, as explained in section 1.8) has been considered. However, modifying the BFIHOST for the net hyetograph calculation only would not be correct, as the same operation should be performed on the north sub-catchment for consistency, and this is not possible as the north sub-catchment flows are obtained through scaling of the full catchment flow estimates. Moreover, the high standing water on site (see section 1.7) is located in the HOST class 5 zone, it is therefore possible that although the soil is extremely permeable the surface water cannot infiltrate because of saturation and/or underlying geology; thus maintaining the whole catchment average BFIHOST value appears a more sensible choice (precautionary approach).

SPRHOST - Figure 13.2 of FEH Volume 3 has been used to estimate SPRHOST from the calculated value of BFIHOST; the updated value is 46.5.

	URBEXT – has been recalculated from 1:50,000 OS Maps according to the new catchment boundary; the catchment is essentially rural (URBEXT₂₀₀₀ = 0.0208). FARL – there are no major online ponds or reservoirs within the catchment. The only pond present in the north sub-catchment (NGR 346320 335830) is not online and therefore not hydrologically significant. This has been verified through OS mapping and aerial imagery. The FEH value of 0.965 has been updated to 1. DPLBAR – has been recalculated using equation 7.1 of FEH Volume 5. The value of DPLBAR has been adjusted to 0.8327. DPSBAR – has been recalculated using GIS software elevation statistics for the updated catchment area. The DPSBAR value for the subject catchment has been altered to 52.9m/km. SAAR – the value of 703mm has been confirmed using 1941-1970 Average Annual Rainfall maps. PROPWET – the low PROPWET value of 0.34 appears correct for this catchment based on its moderate permeability and low rainfall.
Source of URBEXT / URBAN	URBEXT ₂₀₀₀ for both FEH Statistical and ReFH2.
Method for updating URBEXT / URBAN Refer to WINFAP4 Urban Adjustment procedures/guidance	Recalculated urban area (0.0366m ²) has been directly input into WINFAP4 and ReFH2 software.

3. Statistical method

3.1. Search for donor sites for QMED (if applicable)

Note that donor catchments will usually be rural but may be urban provided the data is deurbanised prior to the adjustment process. Please include a map if necessary.

Comment on potential donor sites

Mention:

- number of potential donor sites available
- distances from subject site
- similarities in terms of AREA, BFIHOST, FARL and other catchment descriptors
- quality of flood peak data

WINFAP was used to generate a list of the closest 10 potential donor sites for this ungauged site. Recent research (Doc. Ref. Using Multiple Donor Sites for Enhanced Flood Estimation in Ungauged Catchments, Kjeldsen et al. 2014), recommends the use of multiple donor sites for ungauged catchments, to improve estimation of the flood peak flows.

It must be noted that all the potential donors suggest (if selected as single donor stations) suggest a reduction in the QMED value derived from CDs ($QMED_{CDs}$, $0.402m^3/s$) is appropriate. Therefore, it is likely that the value of $QMED_{CDs}$ is overestimated.

All potential donor stations have catchment areas much larger than the subject catchment (a common problem for small catchments); for this reason, the recommended limit for the AREA descriptor (5 times the subject catchment value) has not been considered a restricting factor when selecting donors.

Due to the hydrological and geographical similarities stations 68005, 68001, and 68020 (individual details discussed below) have been selected for donor transfer.

3.2. Donor sites chosen and QMED adjustment factors

If using WINFAP3 great caution should be taken in urban catchments that are also highly permeable (BFIHOST>0.65). Further details are provided in the EA Flood Estimation Guidelines.

NRFA number	Reasons for choosing or rejecting	Method (AM or POT)	Adjusted for climatic variation?	QMED from (gauged) flow data (A) (m ³ /s)	QMED from flow data with urban influence removed (m ³ /s)	QMEDrural from catchment descriptors (B) (m ³ /s)	Adjustment ratio (A/B)
54016 (Roden @ Rodington)	Rejected ; closest potential donor station (centroid distance of 9km). BFIHOST value (0.615) is higher than subject site and the station has been rejected.	AM	No	10.733	10.522	18.568	0.578
54020 (Perry @ Yeaton)	Rejected ; 2 nd potential donor station (centroid distance of 11.1km). BFIHOST value (0.654) is higher than subject site and the station has been rejected.	AM	No	10.58	10.337	12.927	0.818
68005 (Weaver @ Audlem)	Chosen Donor ; 3 rd potential donor station (centroid distance of 16.23km) with similar catchment descriptors (SAAR 719mm, BFIHOST 0.502, FARL 0.95) and a long data record of 48 years. The station has been chosen as a donor.	AM	No	13.951	13.831	21.617	0.645
54012 (Tern @ Walcot)	Rejected ; 4 th potential donor station (centroid distance of 20.41km). BFIHOST value	AM	No	35.501	34.026	48.032	0.739

	(0.616) is higher than subject site and the station has been rejected.						
54041 (Tern @ Eaton Upon Tern)	Rejected ; 5 th potential donor station (centroid distance of 21.11km). BFIHOST value (0.645) is higher than subject site and the station has been rejected.	AM	No	12.208	11.917	12.793	0.954
68001 (Weaver @ Ashbrook)	Chosen Donor ; 6 th potential donor station (centroid distance of 24.3km). Similar catchment descriptors (SAAR 732mm, BFIHOST 0.513, FARL 0.96) and a very long data record of 80 years. The station has been chosen as a donor.	AM	No	46.677	45.195	58.213	0.802
54044 (Tern @ Ternhill)	Rejected ; 7 th potential donor station (centroid distance of 25.96km). BFIHOST value (0.698) is higher than subject site and the station has been rejected.	AM	No	4.681	4.52	6.191	0.756
54001 (Severn @ Bewdley)	Rejected ; 8 th potential donor station (centroid distance of 27.53km). The stations AREA value is significantly larger than the subject site (4330km ² , approximately 4000x the size of the subject site). SAAR value (912mm) is higher than subject site. For these reasons, the station has been rejected.	AM	No	336.049	327.792	489.319	0.687

67005 (Ceiriog @ Brynkinalt Weir)	Rejected ; 9 th potential donor station (centroid distance of 28.57km). SAAR value (1198mm) is significantly higher than subject site and the station has been rejected.	AM	No	28.93	28.889	49.865	0.580
68020 (Gowy @ Bridge Trafford)	Chosen Donor ; 10 th potential donor station (centroid distance of 28.97km). Similar catchment descriptors (SAAR 729mm, BFIHOST 0.538, FARL 0.99) and a long data record of 38 years. The station has been chosen as a donor.	AM	No	15.168	14.858	18.023	0.842
Has the WINFAP4 urban adjustment method (based on Kjeldsen, 2014) been applied? If not, why?				WINFAP4 urban adjustment has been applied.			

3.3. Overview of estimation of QMED at each subject site

Notes for completing this table

- Methods
 - CD: catchment descriptors alone
 - DT: data transfer
 - BCW: catchment descriptors and bankfull channel width
 - FV: flow variability (using flow duration statistics)
- Urban adjustment procedures should be applied regardless of whether the subject site is rural or urban.
- If using WINFAP3, great caution should be taken in urban adjustment of QMED on catchments that are also highly permeable (BFIHOST>0.65).
- The data transfer procedure is from Science Report SC050050. The QMED adjustment factor A/B for each donor site is given in Table 3.2. This is moderated using the power term, a , which is a function of the distance between the centroids of the subject catchment and the donor catchment. The final estimate of QMED is $(A/B)^a$ times the initial estimate from catchment descriptors.
- If more than one donor has been used, use multiple rows for the site and give the weights used in the averaging. Record the weighted average adjustment factor in the table.

			Data transfer						
Site code	QMEDrural from CDs (m³/s)	Method	NRFA numbers for donor site/s used (see 3.2)	Distance between centroids dij (km)	Moderated QMED adjustment factor (A/B) ^a	If more than one donor		Final estimate of QMEDrural (m³/s)	Final estimate of QMEDurban (m³/s)
						Weight (if WINFAP4 method not used)	Weighted average QMED adjustment factor		
S001	0.402	AM	68005 68001 68020	16.23 24.30 28.97	0.864 0.939 0.957			0.343	0.350
Has the Kjeldsen (2014) urban adjustment method (as used in WINFAP4) been applied? If not, why? How are the weights derived? Are the values of QMED consistent, for example at successive points along the watercourse and at confluences?					Urban adjustment applied in WINFAP4				
					Procedure automatically applied by WINFAP4				
					N/a - No check points available				

3.4. Derivation of pooling groups

The composition of pooling group and other information about the FEH Statistical method are given in Annex 6.3 and 6.4.

Name of group	Site code from whose descriptors group was derived	Subject site treated as gauged? (enhanced single site analysis)	Changes made to default pooling group, with reasons. Include any sites that were investigated but retained in the group
---------------	--	--	--

Cadney Lane	S001	No	WINFAP was used to generate an initial pooling group list (minimum 500 years of data) which was reviewed in order to reject stations that are not hydrologically similar to the catchment of interest. 27073 (Brompton Beck @ Snainton Ings) rejected; First ranked station in default group. Station is highly permeable (BFIHOST 0.887) and therefore not representative of subject site. Station has been rejected from the pooling group. 76011 (Coal Burn @ Coalburn) retained; 2nd ranked station in default group. Catchment has similar values of AREA (1.63km²), FARL (1) and DPLBAR (1.30km); lower although acceptable values of BFIHOST (0.196), and DPSBAR (47.2m/km); higher although acceptable value of SAAR (1096mm). Station description states that 'weir does not drown at high flows'. Natural responsive catchment with no abstractions or additions.' Few high flow gauging's are available to validate the rating curve but site is gauged to within 18% of QMED and weir rating considered broadly reliable (station noted suitable for pooling). Station has 40 years of data and has been retained. 45816 (Haddeo @ Upton) retained; 3rd ranked station in default group. Similar values of FARL (1) and DPSBAR (81m/km); acceptable values of BFIHOST (0.59), AREA (6.81km²), DPLBAR (3.07km) and SAAR (1210mm). The station has a relatively good data record of 24 years and has been retained. 27051 (Crimple @ Burn Bridge) retained; 4th ranked station in the default group. Relatively similar values of DPSBAR (62.9m/km), SAAR (855mm) BFIHOST (0.309) and FARL (1); higher although acceptable values of DPLBAR (2.58km) and AREA (8.17km²). The station has a long data record of 45 years and the measuring authority consider the station 'excellent for peak flow measurements'. Therefore, the station has been retained. 28033 (Dove @ Hollinsclough) retained; 5th ranked station in default group. Similar values of FARL (1) and BFIHOST (0.403); higher although acceptable
-------------	------	----	---

			values of AREA (7.92km²), SAAR (1346mm), DPSBAR (166.7m/km) and DPLBAR (3.14km). Station weir remains fully modular and has never been overtopped; all flows are contained by the structure. Good data record of 38 years. Station has been retained. 20002 (West Peffer Burn @ Luffness) retained; 6th ranked station in default group. Lowland catchment draining flat arable land (DPSBAR is an acceptable 30.9m/km); similar values of BFIHOST (0.47), FARL (0.995), SAAR (616mm) and PROPWET (0.33); higher although acceptable value of DPLBAR (5.7km) Station has a good data record of 41 years and has been retained. 25003 (Trout Beck @ Moor House) retained; 7th ranked station in the default group. Relatively similar values of DPSBAR (92m/km), BFIHOST (0.227) and FARL (1); higher although acceptable values of AREA (11.40km²), DPLBAR (3.29km) and SAAR (1905mm). Rating extrapolation of the station is considered reliable by NFRA. The station has a good data record of 44 years and has been retained. 26802 (Gypsey Race @ Kirby Grindalythe) rejected; 8th ranked station in the default group. Catchment is highly permeable (BFIHOST 0.959) and therefore not representative of the subject catchment. Station has been rejected from the pooling group. 25019 (Leven @ Easby) retained; 9th ranked station in the default group. Similar values of FARL (1), SAAR (830mm) and PROPWET (0.38); higher although acceptable values of AREA (15.09km²), DPLBAR (5.58km) DPSBAR (128m/km) and BFIHOST (0.524). Station has a good data record of 39 years. Noted that the station has the steepest growth curve of this pooling group; likely due to the 4 relatively large events in the AMAX series (water years 1975, 1986, 1992 and 2004). Flows have never been recorded above bank full, gaugings confirm flow to QMED. Highest AMAX flow on record (water year 1975) is much higher than others but the downstream town of Stokesley recorded substantial flooding therefore, the AMAX value is considered validated. The station has good confidence and the highest AMAX
--	--	--	---

			entries are validated by historic flood events downstream. Therefore, the station has been retained for pooling. 91802 (Allt Leachdach @ Intake) rejected; 10th ranked station in default group. Mountainous Scottish Catchment in the Ben Nevis massif. Station has been rejected (although AREA, FARL, DPLBAR and BFIHOST would be acceptable) as SAAR (2554mm), DPSBAR (406.9m/km) and PROPWET (0.83) are too high and imply a completely different rainfall-runoff behaviour of the catchment. 47022 (Tory Brook @ Newnham Park) retained; 11th ranked station in the default group. Relatively similar values of BFIHOST (0.431) and DPSBAR (106m/km); higher though acceptable values of AREA (13.43km²), SAAR (1403mm) and DPLBAR (4.86); lower though acceptable value of FARL (0.942). Rating extrapolated although all kept in bank and 24 years of data; station has been retained. 49006 (Camel @ Camelford) retained; 12th ranked station in the default group. Relatively similar values of DPSBAR (57.5 m/km) and FARL (1); moderately higher value of BFIHOST (0.575), AREA (12.52km²), DPLBAR (3.93km), SAAR (1418mm). Although not gauged above QMED, all flows contained. The station has been retained although the data record of the station is only 11 years (as junior station and no valid reason to reject). 71003 (Croasdale Beck @ Croasdale Flume) retained; 13th ranked station in the default group. Relatively similar values of FARL (1) and BFIHOST (0.276). Higher although acceptable values of AREA (10.71km²), DPLBAR (3.66km), DPSBAR (156.7m/km) and SAAR (1882mm). Ratings by physical and computational models are a good fit to gauging's. The station has a reasonably good data record of 37 years and has been retained. 25011 (Langdon Beck @ Langdon) retained; 14th ranked station in the default group. Relatively similar values of FARL (1) and BFIHOST (0.237). Higher although acceptable values of DPSBAR (123.4m/km), DPLBAR (4.19km),
--	--	--	---

			SAAR (1463mm) and AREA (12.79km²). No bypassing of station reported, well confined and good fit to recorded gauging's. Good downstream fall so no backing up of flow from watercourse downstream, high modular limit and 28 years of data; station has been retained in the pooling group. 49005 (Bolingey Stream @ Bolingey Cocks Bridge) rejected; 15th ranked station in the default group. Similar values of FARL (0.991), SAAR (1044mm) and DPSBAR (81.4m/km). However, higher values of BFIHOST (0.627), AREA (16.08km²), PROPWET (0.42) and DPLBAR (3.72km) and a lower FPEXT (0.0229). Station has only 7 years of data (junior station). The L-Moments graph shows that the station kurtosis is an outlier; for this reason and as numerous descriptors are dissimilar from those of subject site, the station has been rejected. 203046 (Rathmore Burn @ Rathmore Bridge) retained; 16th ranked station in the default group. Relatively similar values of DPSBAR (57.9m/km), BFIHOST (0.429) and FARL (1); acceptably higher values of DPLBAR (6.41km), PROPWET (0.52) and SAAR (1043mm). The station has a reasonably good data record of 35 years and the measuring authority considers the extrapolation of rating of high flow valid, as very minimal floodplain flow. Station has been included in the pooling group. <i>The following stations were investigated for inclusion to increase the number of station-years within the pooling group:</i> 92002 (Allt Coire Nan Con @ Polloch) not added; first ranked station after those rejected from the default group. Acceptable values of AREA (8.06km²), DPLBAR (3.74km), BFIHOST (0.359) and FARL (0.989). However, values of DPSBAR (290.3m/km), PROPWET (0.8) and SAAR (2541mm) are too high and the station has not been added as it is not considered to be representative of the subject catchment.
--	--	--	--

			54022 (Severn @ Plynlimon Flume) not added; 2nd ranked station after those rejected from the default group. Acceptable values of AREA (8.75km²), FARL (1), DPLBAR (2.94km) and BFIHOST (0.323). However, values of SAAR (2481mm), DPSBAR (180.3m/km), and PROPWET (0.66) are high as NRFA describes the site as a 'very wet and steep catchment', which is not representative of the subject site. Therefore, the station has not been added to the pooling group. 206006 (Annalong @ Recorder) not added; 3rd ranked station after those rejected from the default group. Acceptable values of AREA (14.44km²), DPLBAR (3.44km), BFIHOST (0.336), FARL (0.981). However, SAAR (1704mm) and PROPWET (0.53) values are relatively high and DPSBAR (270.8 m/km) is significantly higher, indicating a steep catchment, which is not representative of the subject site. Therefore, the station has not been added to the pooling group. 49003 (de Lank @ de Lank) added; 4th ranked station after those rejected from the default group. Similar values of BFIHOST (0.379), FARL (0.998) and DPSBAR (76m/km); higher although acceptable values of DPLBAR (4.78km), PROPWET (0.45) and SAAR (1628mm). Flow is modified by public water supply works, but it is assumed that the influence on AMAX values is minimal. No reported bypassing or drowning and theoretical rating expected to perform well. Long data record of 51 years. Station has been added to the pooling group. 27010 (Hodge Beck @ Bransdale Weir) added; 5th ranked station after those rejected from the default group. Similar values of FARL (1), BFIHOST (0.341), SAAR (987mm) and PROPWET (0.40). Station has a good data record of 41 years and the measuring authority considers flow estimates to be reliable. Added to the pooling group. 44008 (South Winterbourne @ Winterbourne Steepleton) not added; 6th ranked station after those rejected from the default group. Station has acceptable values of DPLBAR (5.05km), PROPWET (0.38), FARL (1),
--	--	--	--

			DPSBAR (93.8m/km) and SAAR (1012mm); however, station has a high BFIHOST (0.811) value as the catchment geology is chalk (not representative of subject catchment). Some minor flow bypassing is highlighted. Furthermore, station has sharper growth curve than other representative stations in the pooling group. The catchment is deemed not representative of the subject catchment and has not been added to the pooling group. 72014 (Conder @ Galgate) added; 7th ranked station after those rejected from the default group. values of BFIHOST (0.443), FARL (0.975) and DPSBAR (93.4m/km); higher although acceptable values of PROPWET (0.60) and SAAR (1183mm). Long data record of 49 years. Station has been added to the pooling group. The final pooling group contains 547 years of data.
5URBEXT2000 threshold used to create pooling group(s)	Recommend value of 0.03 has been used.		

3.5. Derivation of flood growth curves at subject sites

Notes for completing this table

- Abbreviations for method types
 - SS: single site
 - P: pooled
 - ESS: enhanced single site
 - FH: single site with flood history
- A pooling group (or ESS analysis) derived at one gauge can be applied to estimate growth curves at a number of ungauged sites. Each site may have a different urban adjustment, and therefore different growth curve parameters.
- Urban adjustments to growth curves should use the latest methodologies in WINFAP
- Any relevant frequency plots from WINFAP, particularly showing any comparisons between single-site and pooled growth curves (including flood peak data on the plot) should be shown here or in a project report.

Site code	Method (SS, P, ESS, FH)	If P, ESS, or FH, name of pooling group (3.4)	Distribution used and reason for choice	Note any urban adjustment or permeable adjustment	Parameters of distribution (location, scale, and shape) after adjustments	Growth factor for 100-year return period
S001	P	Cadney Lane	GL - best fit in WINFAP (Z value of 0.7692)	Urban adjustment within WINFAP4 applied.	Location: 1 Scale: 0.222 Shape: -0.233 Bound: 0.047	2.823

3.6. Flood estimates from the statistical method

Site code	Flood peak (m ³ /s) for the following return periods (in years)								
	2	20	30	100	100+25%	100+70%	1000		
S001	0.350	0.679	0.747	0.989	1.236	1.681	1.681		

4. Revitalised flood hydrograph (ReFH2) method

4.1. Parameters for ReFH2 model

If parameters are estimated from catchment descriptors, they are easily reproducible so it is not essential to enter them in the table.

Site code	Details of method OPT: optimisation BR: base flow recession fitting CD: catchment descriptors DT: data transfer	T _p (hours) Time to peak	C _{max} (mm) maximum storage capacity	BL (hours) baseflow lag	BR baseflow recharge
S001	CD	1.67	301.24	27.26	0.9
Brief description of any flood event analysis carried out Provide further details either here or in a project report		N/a			

4.2. Design events for ReFH2 method

We recommend that the ReFH2 technical guidance should be referred to when completing this table

Site code	Season of design event (summer or winter)	Storm duration (hours)	Storm area for ARF (if not catchment area)	Source of design rainfall statistic (FEH13 or FEH99)
S001	Winter	2.75	Catchment area	FEH13
Detail any changes to the default ReFH2 urbanisation model parameters Are the storm durations likely to be changed in the next stage of the study For example by optimisation within a hydraulic model?		Urbanised area updated to 0.0366km ²		
		Storm duration is unlikely to be changed.		

4.3. Flood estimates from the ReFH2 method (urban)

- Please indicate whether you have used urban or rural results: urban results are reported.
- We recommend that urban results are used regardless of the extent of urbanisation at the subject sites

Site code	Flood peak (m ³ /s) for the following return periods (in years)								
	2	20	30	100	100+25%	100+70%	1000		
S001	0.564	1.317	1.488	2.083	2.604	3.542	3.518		

4.4. Net rainfall estimates from the ReFH2 method (urban)

Site code	Net rainfall peak (mm/timestep (15 mins)) for the following return periods (in years)								
	2	20	30	100	100+25%	100+70%	1000		
S001	1.17	2.87	3.26	4.61	5.76	7.83	7.85		

ReFH2 hydrographs and hyetographs are reported in Annex 5.5

5. Discussion and summary of results

5.1. Comparison of results from different methods

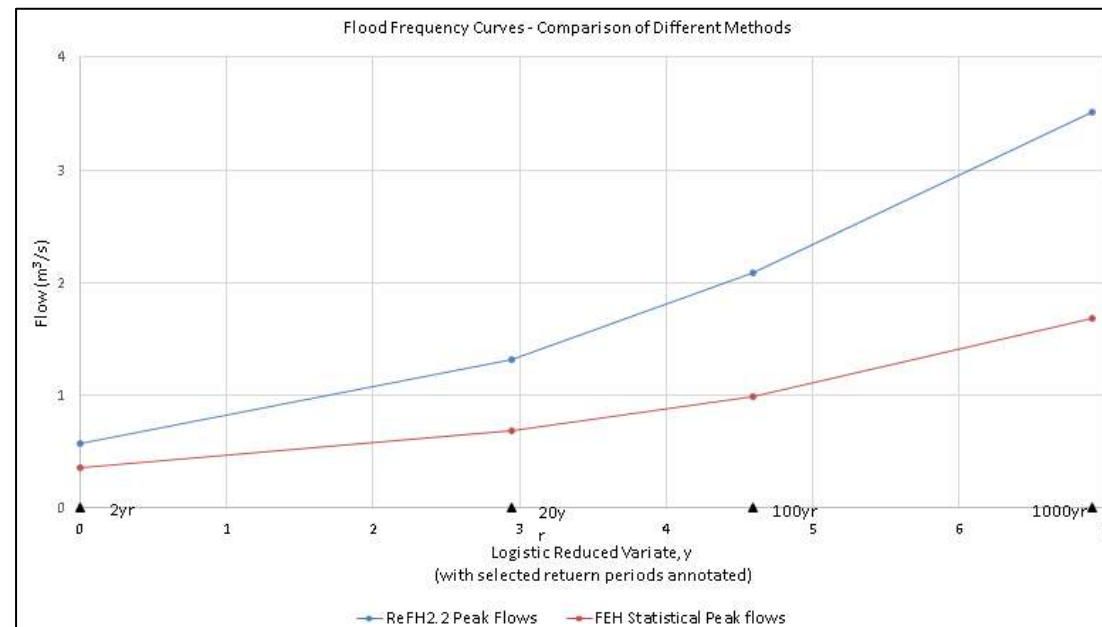
This table compares peak flows from the ReFH2 method with those from the FEH Statistical method at each site for two key return periods.

Site code	Return period 2 years (QMED)			Return period 100 years		
	Statistical	ReFH2	Ratio (ReFH2 / statistical)	Statistical	ReFH2	Ratio (ReFH2 / statistical)
S001	0.350	0.564	1.6126	0.989	2.083	2.1066

5.2. Final choice of method

Choice of method and reasons
Include reference to type of study, nature of catchment, and type of data available

As detailed above, the ReFH2 and FEH Statistical methods have been investigated during the analysis. The following graph shows the growth curves of the two methods.



As shown in the above graph, the ReFH2 results are consistently higher (up to 100% for the Q1000 event) than the FEH Statistical results for all return periods. There is no existing gauged data or previous hydrological analysis which could suggest which of the two methods (FEH Statistical and ReFH2) is more reliable; however, in absence of additional local information, FEH Statistical has been preferred as it makes best use of nearby gauged data from hydrologically similar catchments, and as observed in recent NRW guidelines, gauged data is to be preferred where available.

Furthermore, the ReFH2 method will be used to prepare the net hyetograph which will be applied to the south sub-catchment (see section 1.8 above); using the ReFH2 method for both the fluvial and pluvial inputs of the model could significantly overestimate the final flow at site.

The FEH Statistical method provides peak flows only, to prepare the required input hydrographs, the ReFH2 design hydrographs have been scaled to match the FEH Statistical peaks for each design event.

The FEH statistical method is not recommended for longer return periods (>0.67%AEP or Q150). Therefore, the ratio method has been adopted for the 0.1% AEP return period event. In line with FEH recommendations the 0.1% AEP peak flow estimate has been adjusted utilising the ReFH2 growth curve results, as follows:

$$Q_{1000} = (Q_{1000\text{ReFH2}} / Q_{100\text{ReFH2}}) \times Q_{100\text{FEH Statistical}} = (3.518\text{m}^3/\text{s} / 2.083\text{m}^3/\text{s}) \times 0.989\text{m}^3/\text{s}$$

$$Q_{1000 \text{ adjusted statistical peak}} = 1.670\text{m}^3/\text{s}$$

5.3. Assumptions, limitations, and uncertainty

List the main assumptions made specific to the study	No significant or unusual assumptions have been made. The study catchment is treated as ungauged. The hydraulic model will use a fluvial input (north sub-catchment) and a pluvial input (south sub-catchment). This was considered the most appropriate approach given the specific features of the catchment. The catchment boundary and descriptors have been re-defined appropriately.
Discuss any particular limitations For example applying methods outside the range of catchment types or return periods for which they were developed	The Q1000 flows have been derived through the ratio method and have a degree of uncertainty.
Give what information you can on uncertainty in the results For example using the methods detailed in 'Making better use of local and historic data, and estimating uncertainty in FEH design flood estimation (FEH Local) SC130009	Confidence limits of 95% (as calculated by WINFAP4) on FEH Statistical derived QMED (3 donors) of 0.350m³/s: Lower limit = 0.181m³/s Upper limit = 0.676m³/s Confidence Limits of 95% on ReFH2 derived QMED of 0.564m³/s: Lower Limit = 0.258m³/s Upper Limit = 1.236m³/s
Comment on the suitability of the results for future studies For example at nearby locations or for different purposes	This study has employed the most up-to-date flood estimation software and guidance and, therefore, these results are applicable for future studies. However, it is recommended that future studies update the hydrological assessment to incorporate any developments in

Give any other comments on the study For example suggestions for additional work	methods/software and additional years of flow gauging within the pooling group and donor stations. Separate studies for the north and south sub-catchments could also be investigated although the resultant flood risk to the site is unlikely to be altered.
	No other comments

5.4. Checks

Are the results consistent, for example at confluences?	N/a: ungauged catchment.
What is the 100-year growth factor? Is this realistic? (The guidance suggests a typical range of 2.1 - 4.0)	ReFH2 = 3.691 FEH-Statistical = 2.826
	The growth factor is within the typical range for both result sets.
If 1000-year flows have been derived, what is the range of ratios for the 1000-year flow over 100-year flow?	ReFH2 = 1.689 FEH-Statistical = 1.7
What is the range of specific runoffs (l/s/ha)? Are there any inconsistencies?	Catchment area= 1.107km ² = 110.7ha. 1 in 100 yr peak (FEH Stat) =0.989m ³ /s =989l/s. Specific runoff equates to 8.934l/s/ha.
How did the results compare with those of other studies? Explain any differences and conclude which results should be preferred	N/a: no other studies available for comparison.
Are the results compatible with the longer-term flood history?	N/a: historical food data not available.

Describe any other checks on the results

No other checks performed.

5.5. Final results

Design hydrograph flood peak (m ³ /s) for the following return periods (in years)									
Site code	2	20	30	100	100+25%	100+70%	1000		
S001	0.35	0.68	0.75	0.99	1.24	1.68	1.67		

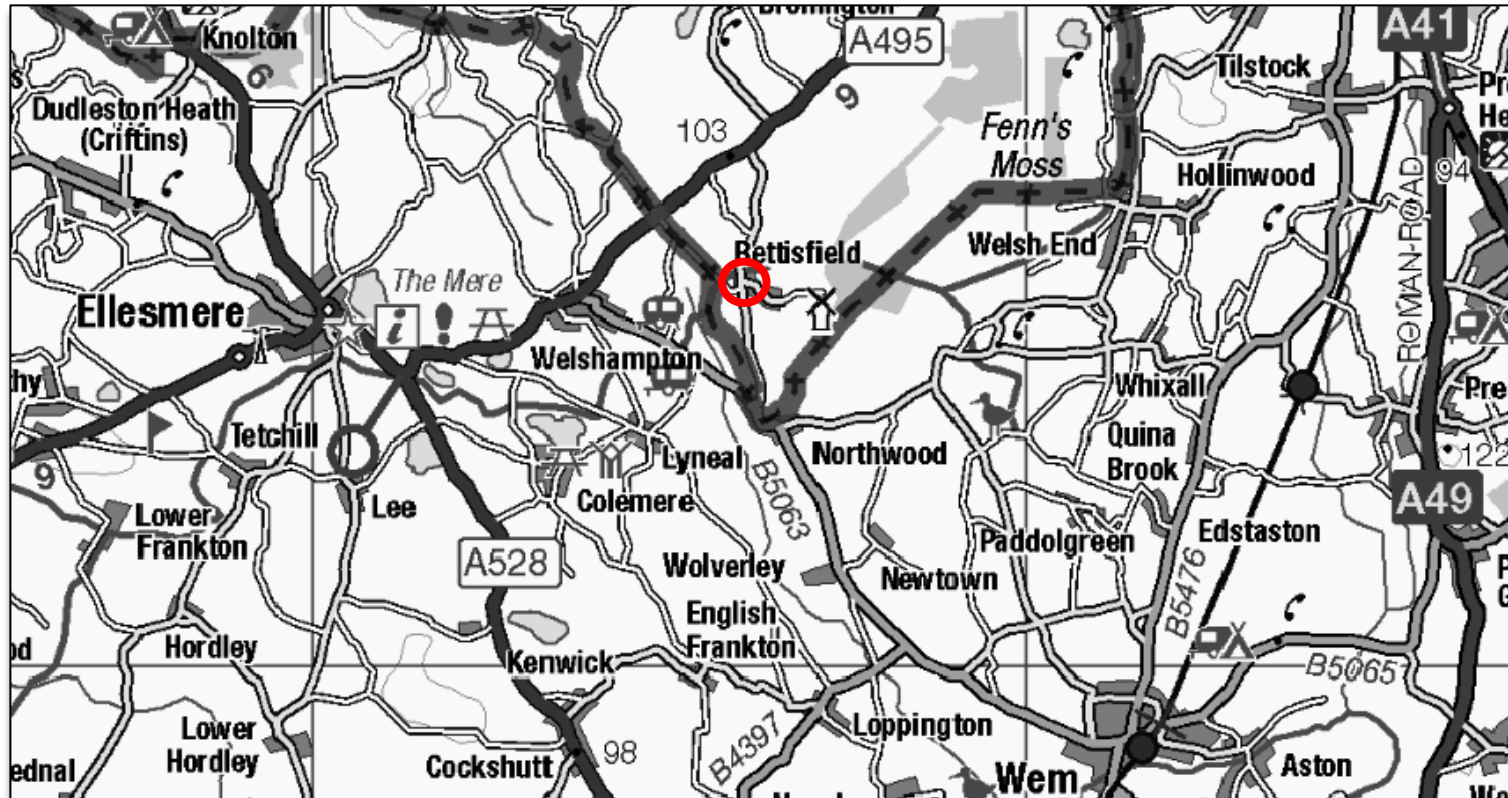
Net rainfall peak (mm/timestep) for the following return periods (in years)									
Site code	2	20	30	100	100+25%	100+70%	1000		
S001	1.17	2.87	3.26	4.61	5.76	7.83	7.85		

If flood hydrographs are needed for the next stage of the study, where are they provided?
For example give a name of spreadsheet, name of hydraulic model, or reference to table below

The design hydrographs and hyetographs are provided in Annex 6.6

6. Annex – supporting information

6.1. Site Location and Photographs



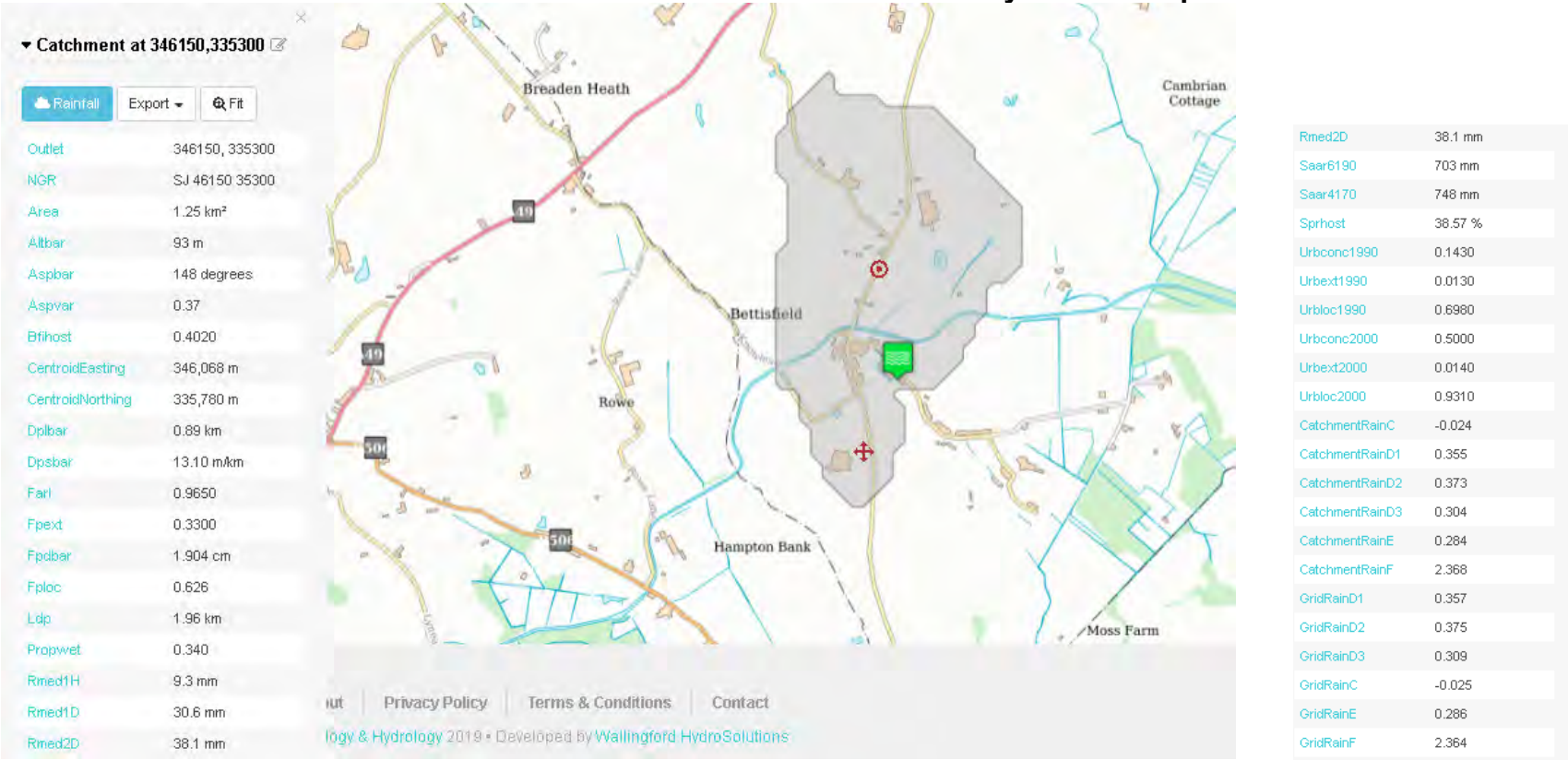




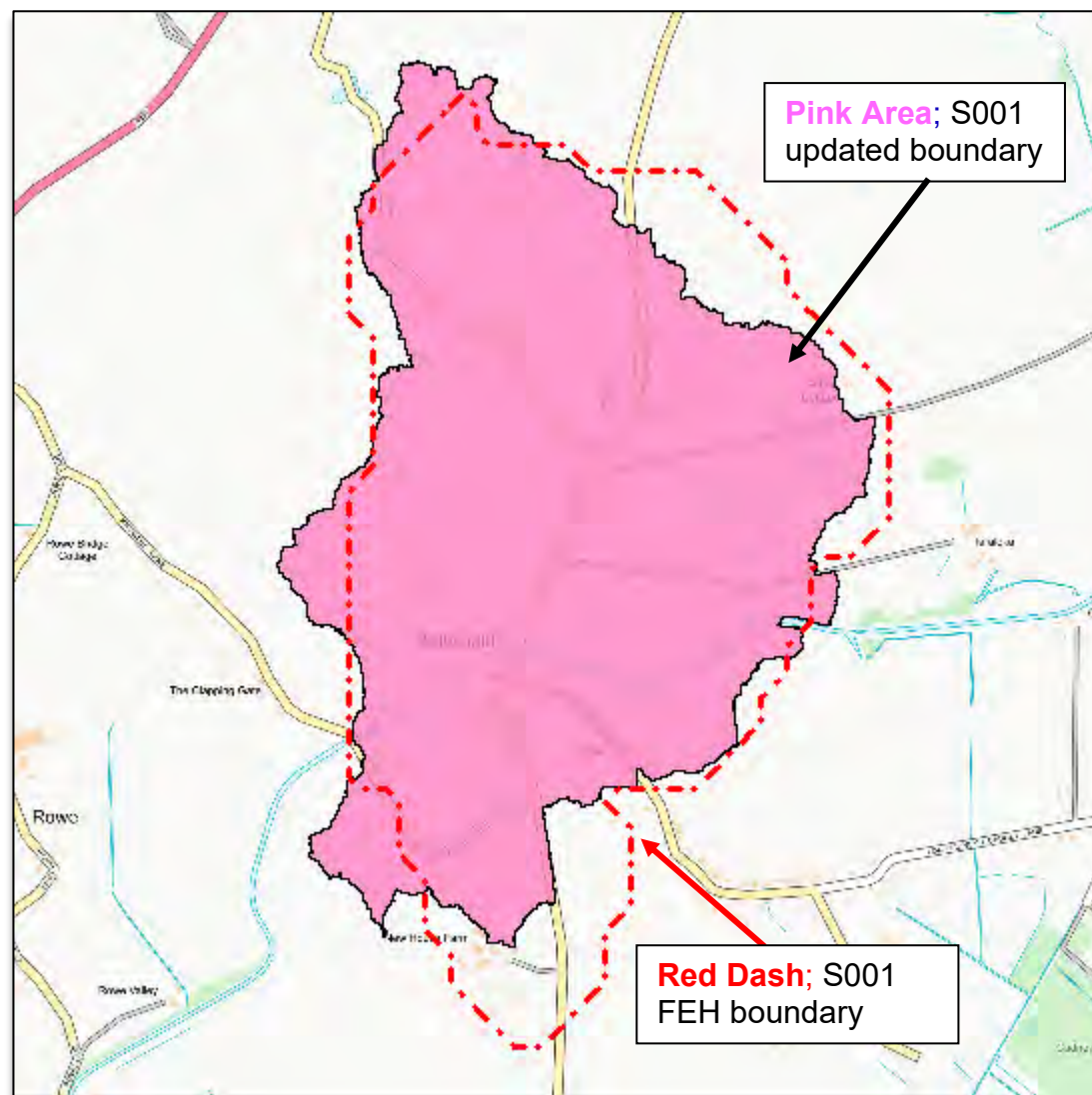
Aerial photographs of the site.

6.2. Catchment Boundary, Descriptors, Sub-catchments and Soil Maps

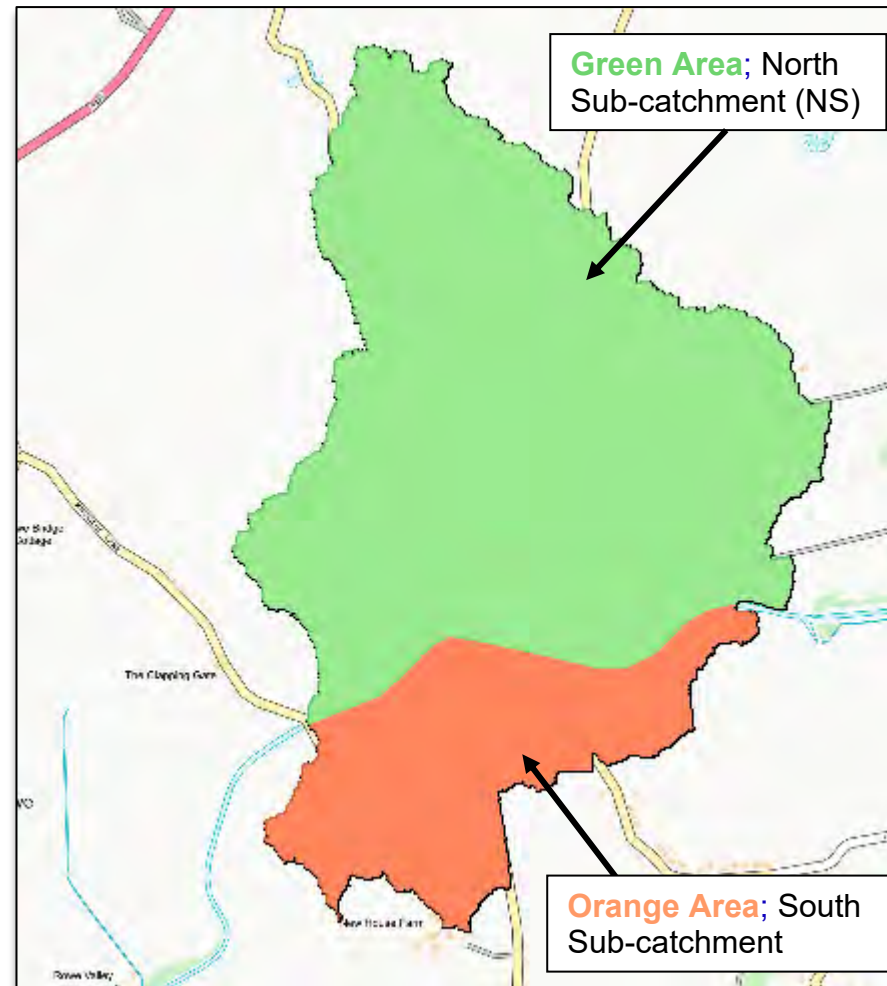
FEH Web Service Catchment Boundary and Descriptors



Catchments Boundary Re-calculation



Sub-catchments



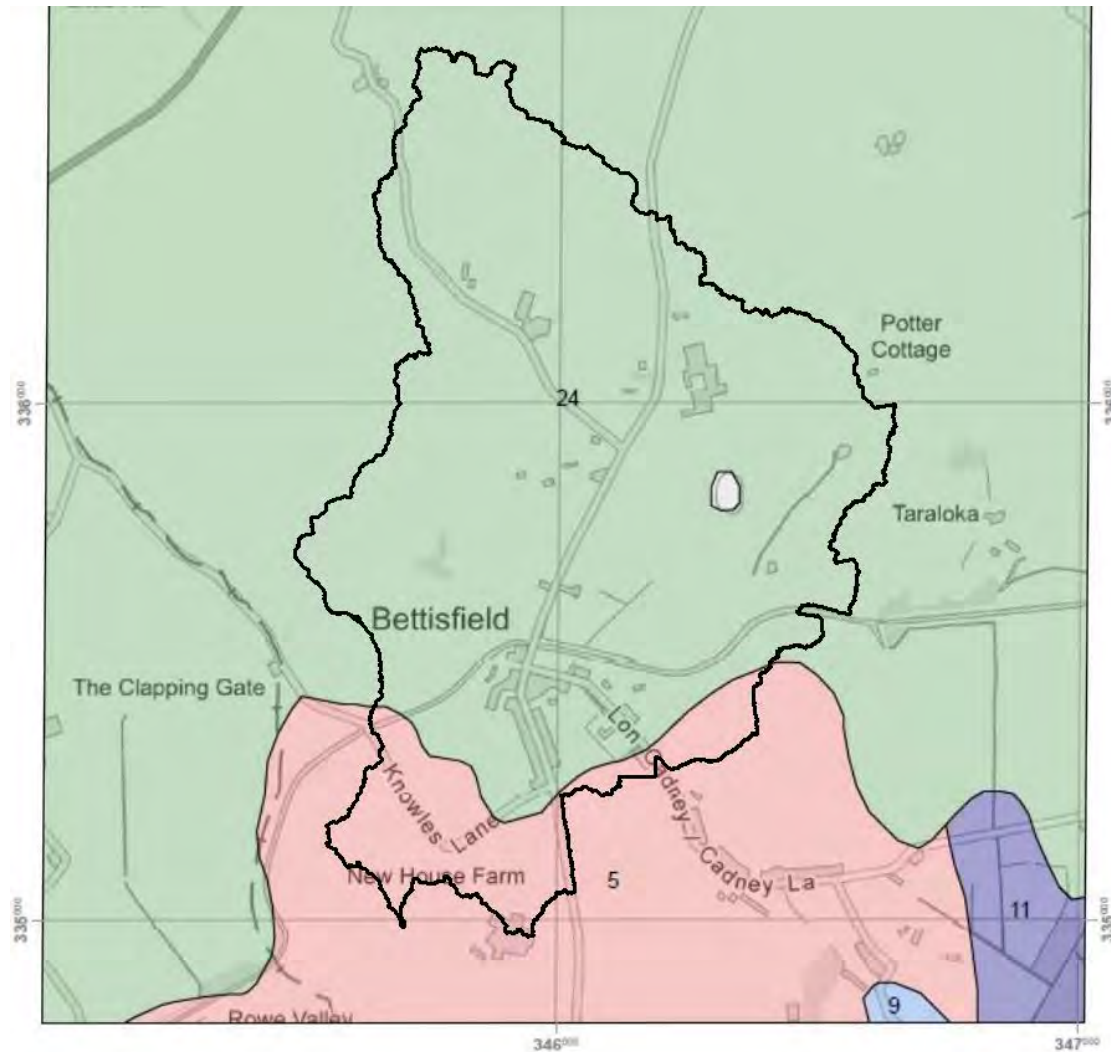
Hydrology of Soil Type (HOST) Map

National Soil Resources Institute



Hydrology of Soil Type (HOST) Key

- 5 Free draining permeable soils in unconsolidated sands or gravels with relatively high permeability and high storage capacity
- 9 Soils seasonally waterlogged by fluctuating groundwater and with relatively slow lateral saturated conductivity
- 11 Drained lowland peaty soils with groundwater controlled by pumping
- 24 Slowly permeable, seasonally waterlogged soils over slowly permeable substrates with negligible storage capacity



6.3. FEH Statistical - Pooling group composition

Pooled & QMED Analysis Dashboard 999200 (05-04-2019 17:28)

AM Data Catchment Descriptors

	Station	Distance	Years of data	QMED AM	L-CV	L-SK
1	76011 (Coal Burn @ Coalburn)	3.037	40	1.840	0.166	0.31
2	45816 (Haddeo @ Upton)	4.494	24	3.489	0.306	0.38
3	27051 (Crimple @ Burn Bridge)	4.523	45	4.564	0.221	0.14
4	28033 (Dove @ Hollinsclough)	4.699	38	4.225	0.234	0.40
5	20002 (West Peffer Burn @ Lulfness)	4.941	41	3.299	0.292	0.01
6	25003 (Trout Beck @ Moor House)	4.967	44	15.142	0.168	0.25
7	25019 (Leven @ Easby)	5.045	39	5.677	0.340	0.31
8	47022 (Tory Brook @ Newnham Park)	5.078	24	6.651	0.265	0.11
9	49006 (Camel @ Camelford)	5.085	11	11.154	0.124	-0.14
10	71003 (Croasdale Beck @ Croasdale Flume)	5.087	37	10.900	0.212	0.31
11	25011 (Langdon Beck @ Langdon)	5.122	28	15.878	0.238	0.31
12	203046 (Rathmore Burn @ Rathmore Bridge)	5.153	35	10.720	0.147	0.14
13	49003 (de Lank @ de Lank)	5.354	51	14.324	0.225	0.20
14	27010 (Hodge Beck @ Bransdale Weir)	5.377	41	9.420	0.224	0.25
15	72014 (Conder @ Galgate)	5.430	49	16.283	0.220	0.11
16						
17	Total		547			
18	Weighted means				0.225	0.22

Key

- Short Records
- Discordant
- No Pooling
- No Pooling, No QMED

Use of at-site data

URBEXT 2000: 0.0208 Suitable for pooling: No
(Pool limit: 0.0000) Suitable for QMED: No

There is no AMAX or POT data available for this catchment.

Urbanisation

Method: User Defined

UAF: 1.020

☒ Show urbanised Flood Frequency results

Edit Urbanisation Method

QMED

Method: Donor Station(s)

QMED: 0.350 m³/s

Urbanised

Edit QMED Method

Heterogeneity measure de...

Number of simulations

500

Edit No. Simulations

L-CV / L-skewness distance

Observed average

0.1204

Simulated mean of average

0.0801

Simulated S.D. of average

0.0151

Standardised test value H2

2.6594

The pooling group is heterogeneous and a review of the pooling group is desirable.

Standard deviation of L-CV

Observed

0.0526

Simulated mean

0.0299

Simulated S.D.

0.0060

Standardised test value H1

3.7939

Heterogeneous

Save

Cancel

Goodness-of-fit details

Number of simulations

500

Edit No. Simulations

Fitting	Z value	
Gen. Logistic	0.7692	*
Gen. Extreme Value	-0.8612	*
Pearson Type III	-2.6059	
Gen. Pareto	-4.7736	

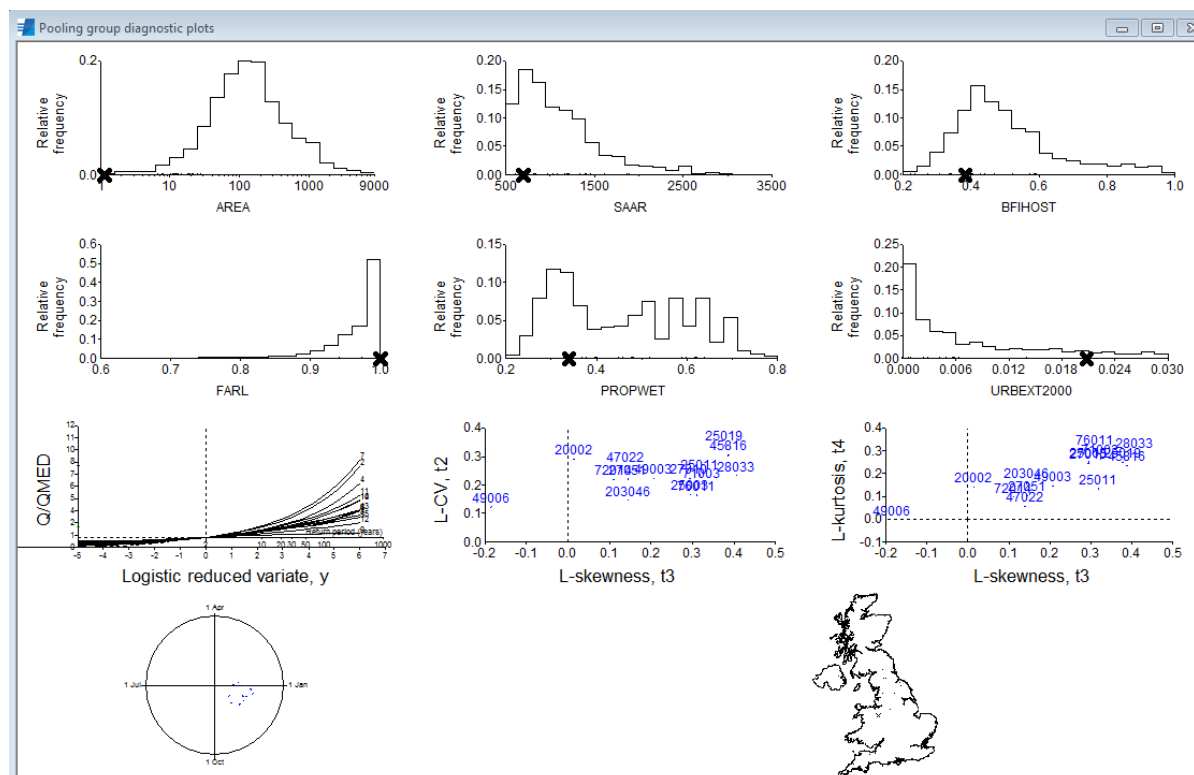
Lowest absolute Z-value indicates best fit

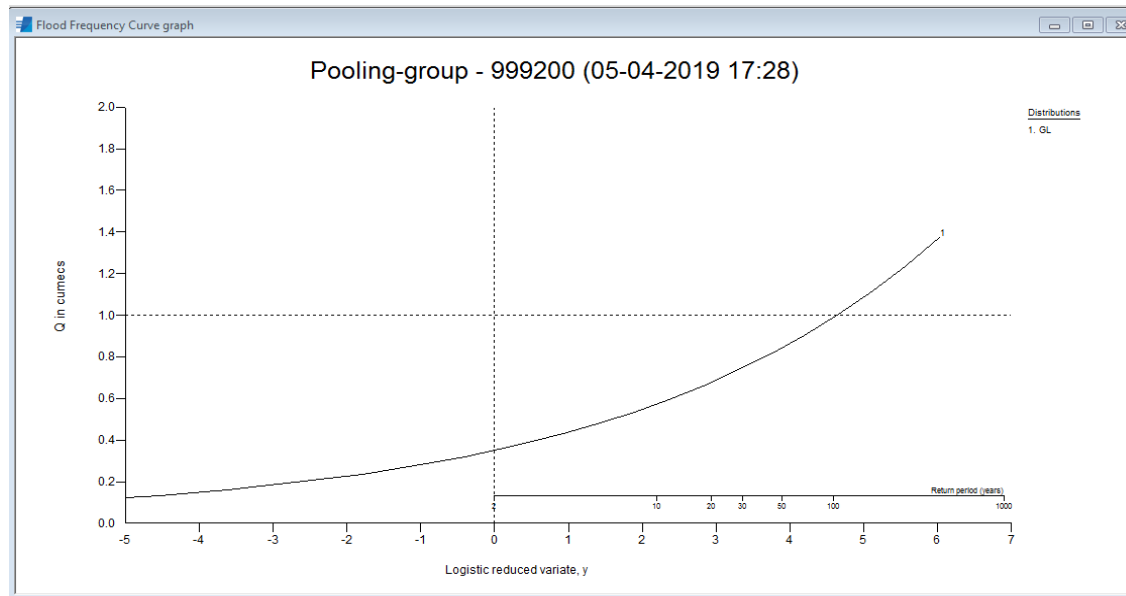
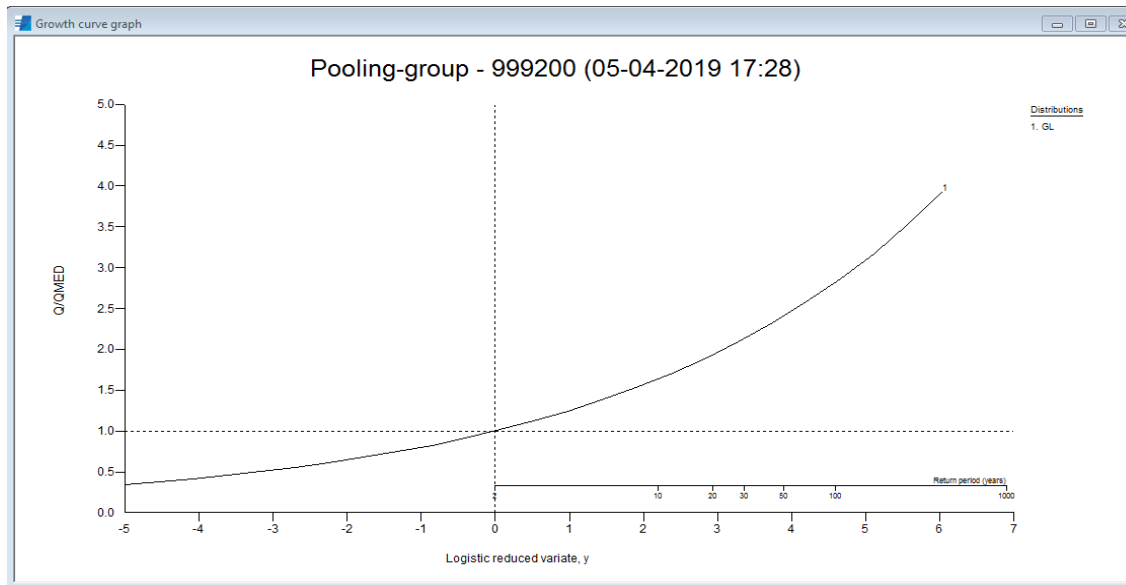
* Distribution gives an acceptable fit (absolute Z value < 1.645)

Save

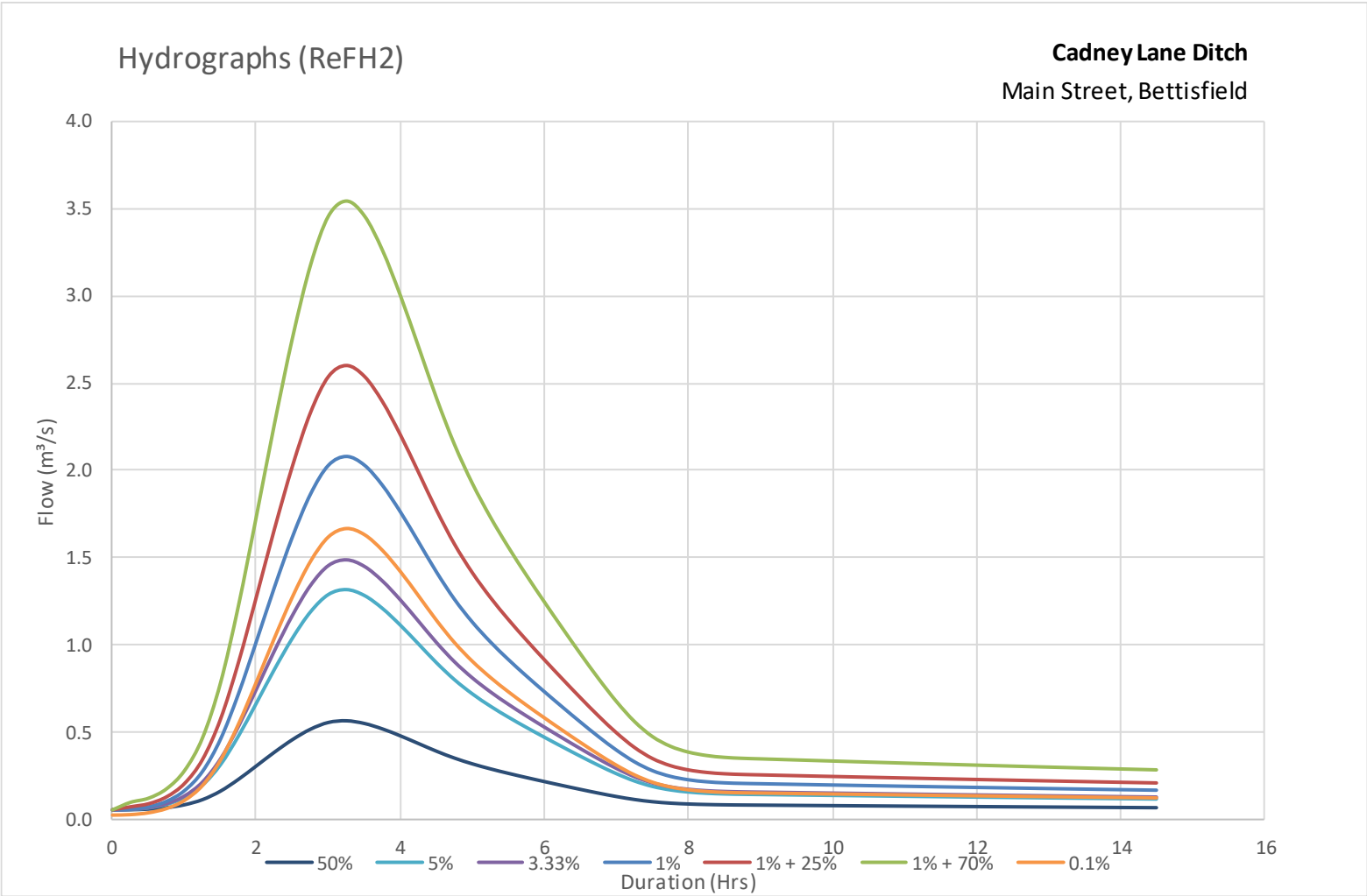
Cancel

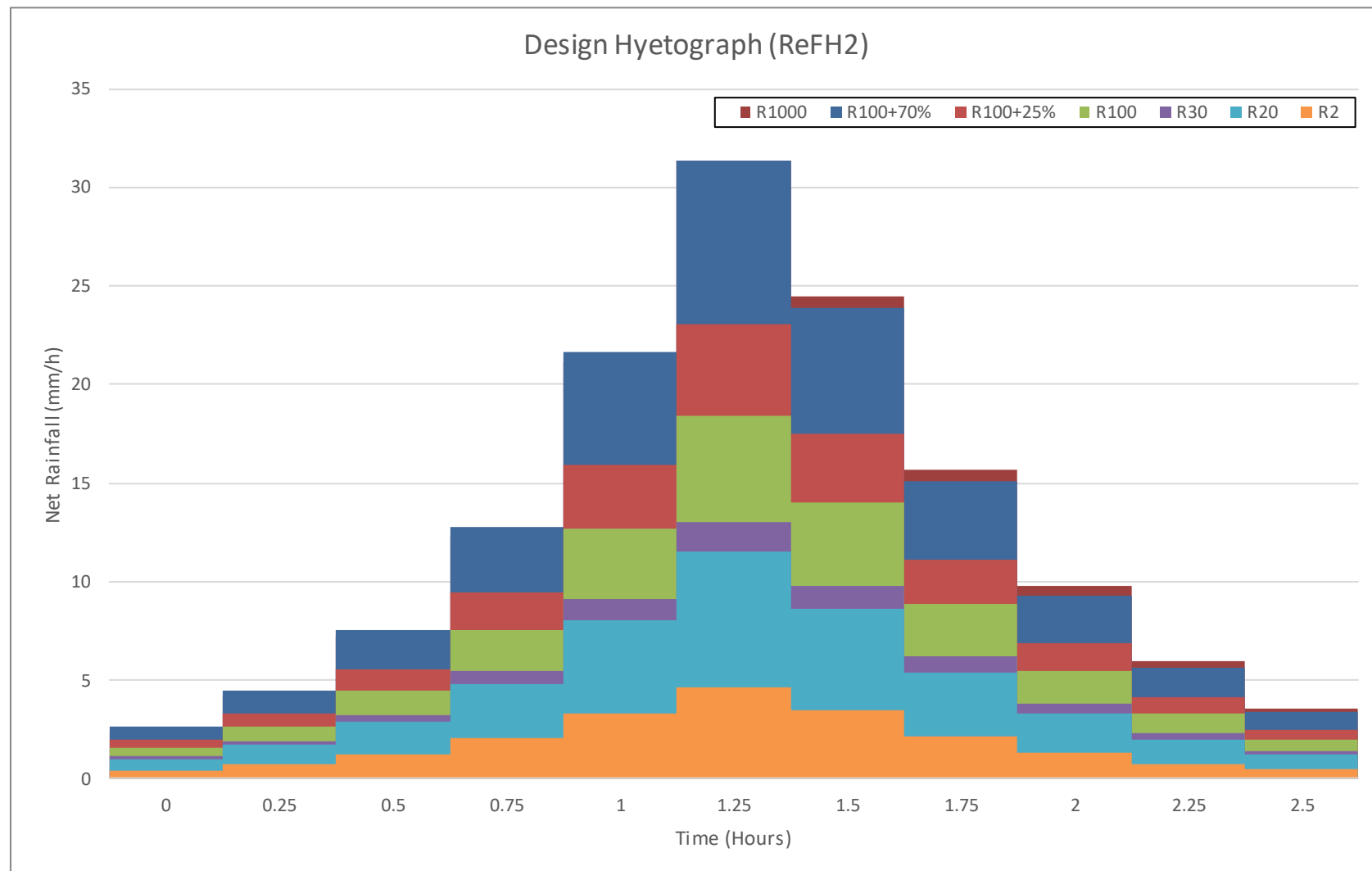
6.4. FEH Statistical – Additional Information





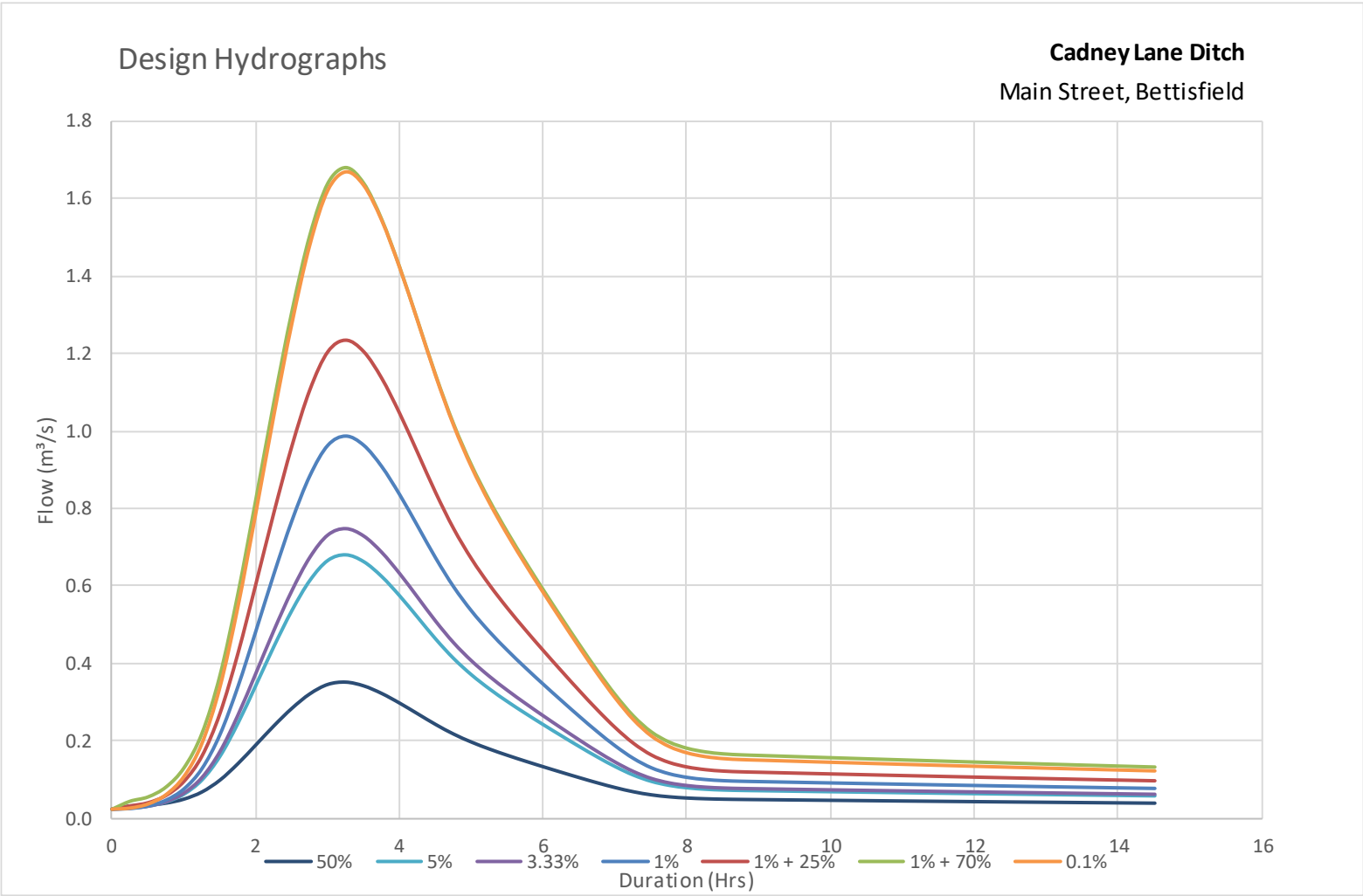
6.5. ReFH2 Hydrographs and Hyetographs (full site)





6.6. Final Design Hydrographs

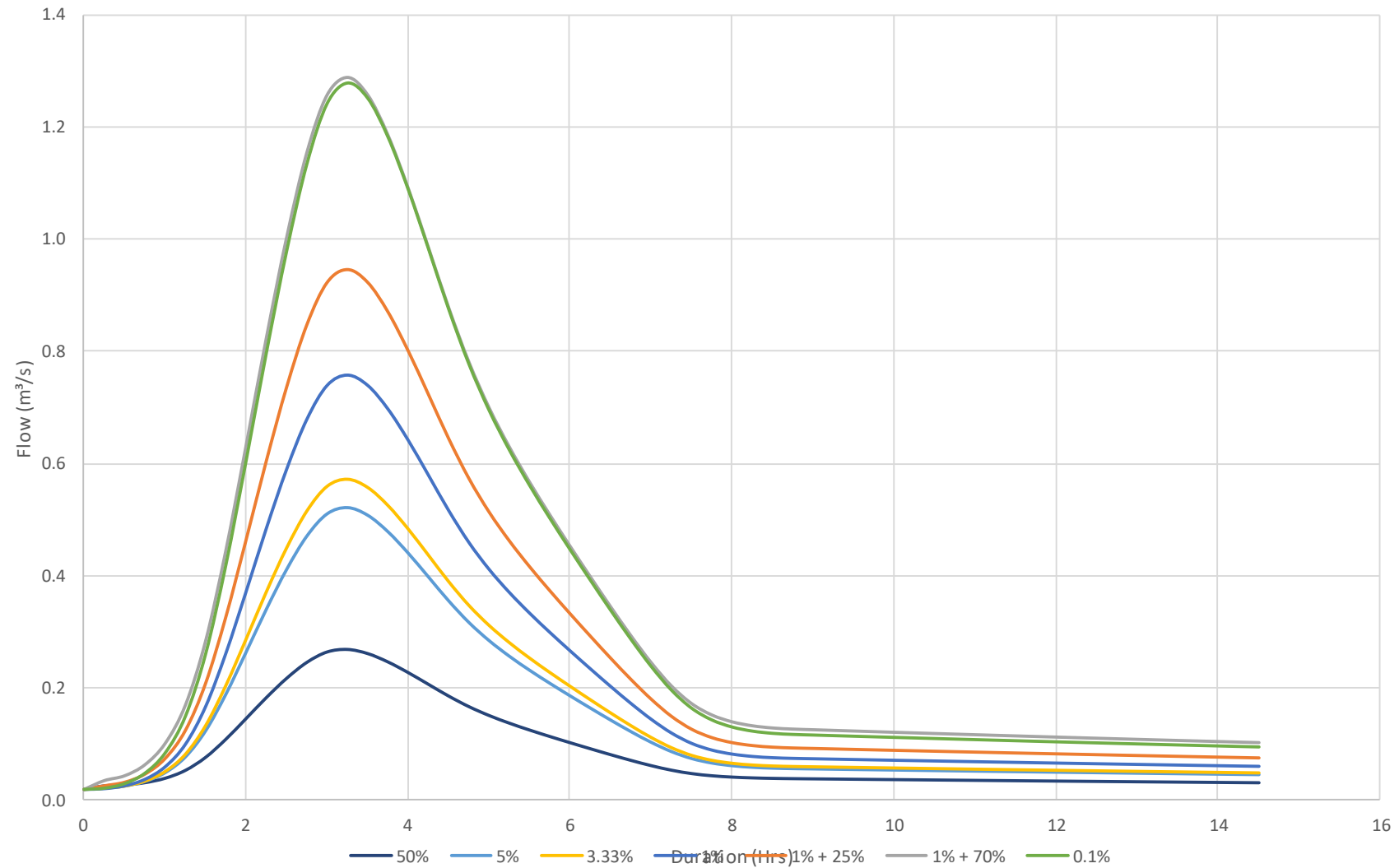
Full site (S001)



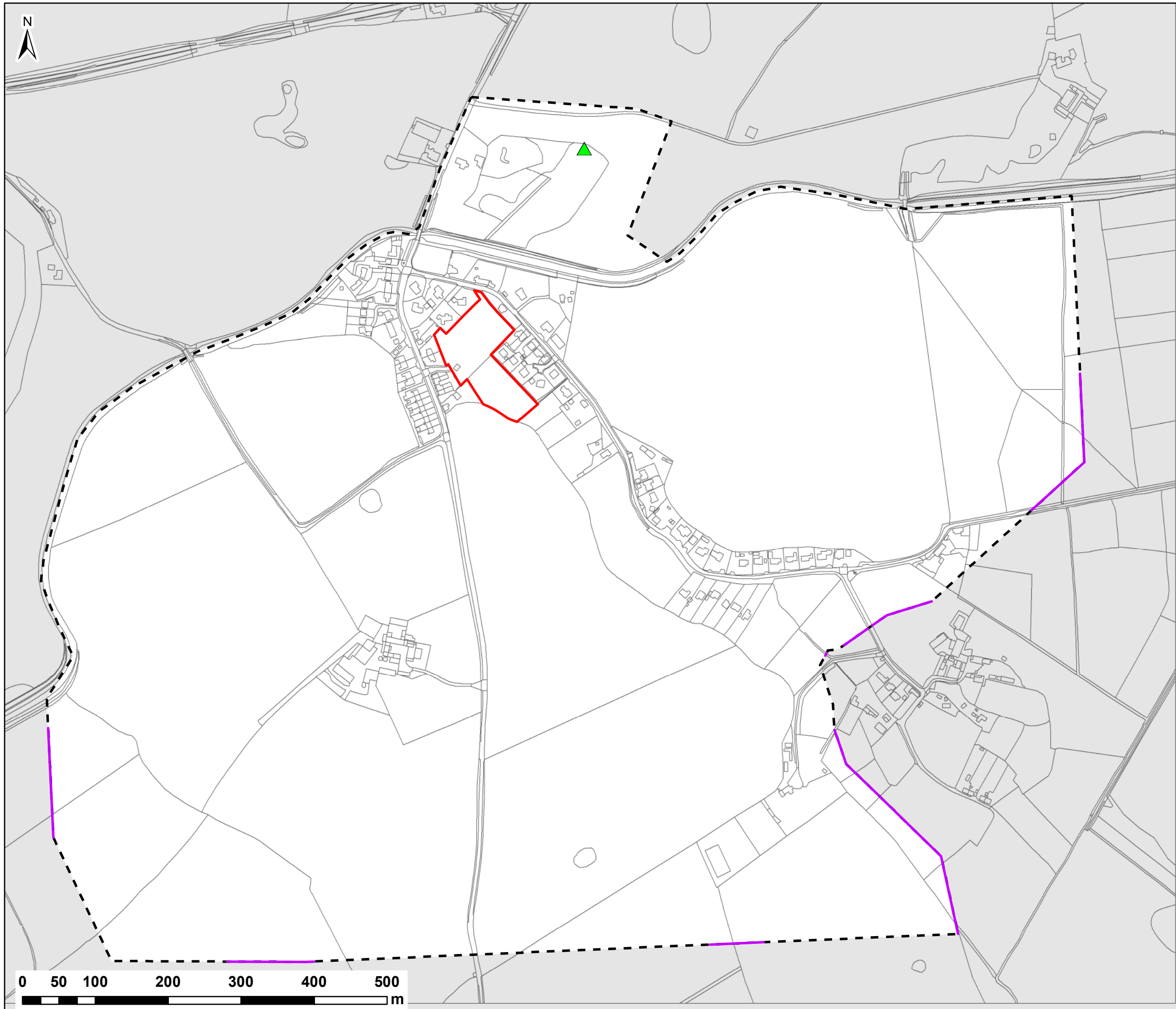
North Sub-Catchment (NS)

Design Hydrographs (North Sub-catchment)

North Sub-catchment



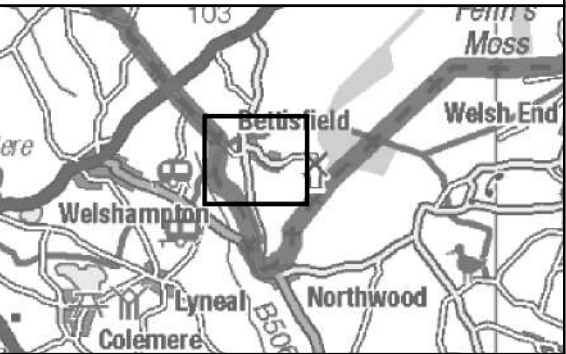
Appendix F 2D Model Extents



NOTES:
1) ALL DIMENSIONS ARE IN METRES AND ALL LEVELS IN METRES ABOVE ORDNANCE DATUM UNLESS STATED OTHERWISE

LEGEND

-  Site Boundary
-  Model Extent
-  1D Model Inflows
-  Downstream Boundary



CLIENT:

TAYLOR REED HOMES LTD



www.waterco.co.uk

SCHEME:

**MAIN STREET,
BETTISFIELD**

PLOT TITLE:

2D MODEL EXTENT

PLOT STATUS:

FINAL

DATE:

29/01/2020

DRAWN:

VJ

CHECKED:

DH

APPROVED:

AR

PLOT SCALE @ A3:

1:5,000

(UNLESS STATED OTHERWISE)

PLOT NAME:

12296-Model_Extent_2D

REV:

-

Appendix G NRW Email correspondence

Sandeep Bomminayuni

From: Knowles, Ryan <Ryan.Knowles@cyfoethnaturiolcymru.gov.uk>
Sent: 03 May 2019 09:43
To: Bethan LloydJones
Subject: Bettisfield

Categories: Information received

Hi Bethan,

Thanks for your telephone call yesterday.

I've had a very quick chat with my Flood Mapping Colleagues about the siltation query. Taking a precautionary approach, the baseline model should represent the channel and structures as surveyed in your recent topo survey (i.e. 90% of culvert cross section not available because of silt). You could then undertake sensitivity testing to show how flood risk is affected by channel maintenance.

I hope this helps.

Thanks, Ryan

Ryan Knowles

Arbenigwr Technegol Datblygiad a Risg Llifogydd / Development and Flood Risk Technical Specialist

Cyfoeth Naturiol Cymru / Natural Resources Wales

Ffordd Gaer, Bwcle, Sir y Fflint, CH7 3AJ / Buckley Office, Chester Road, Buckley, CH7 3AJ.

Ffôn/Tel: 0300 065 3906

Dysgwyr Cymraeg

cyfoethnaturiol.cymru / naturalresources.wales

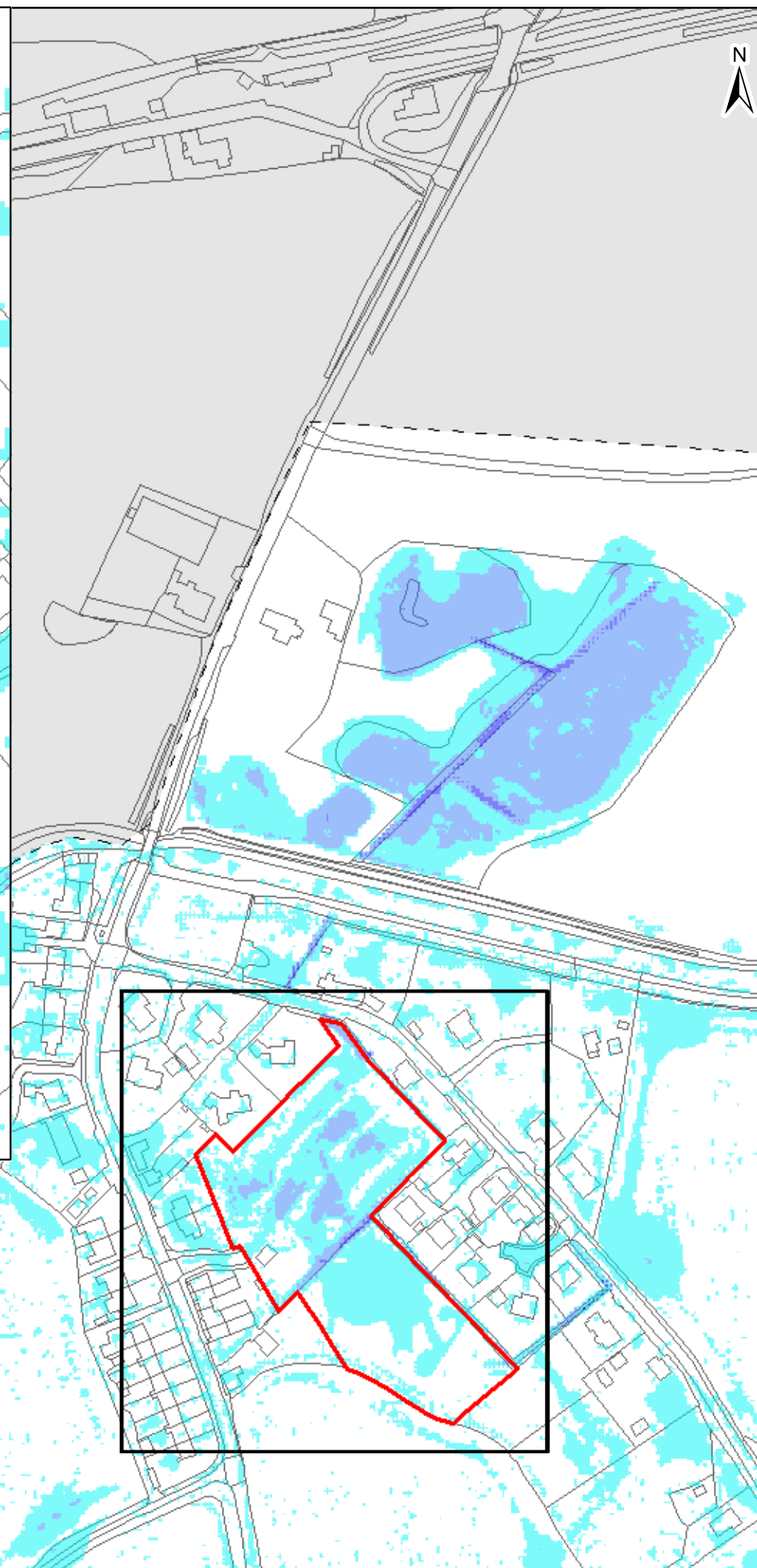
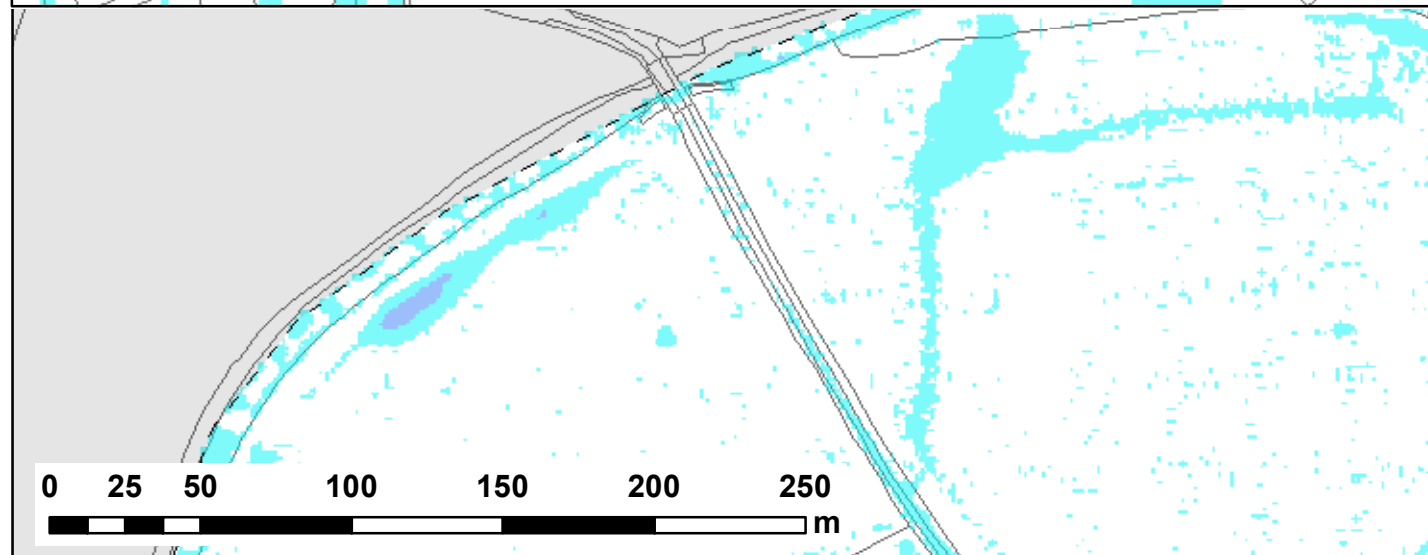
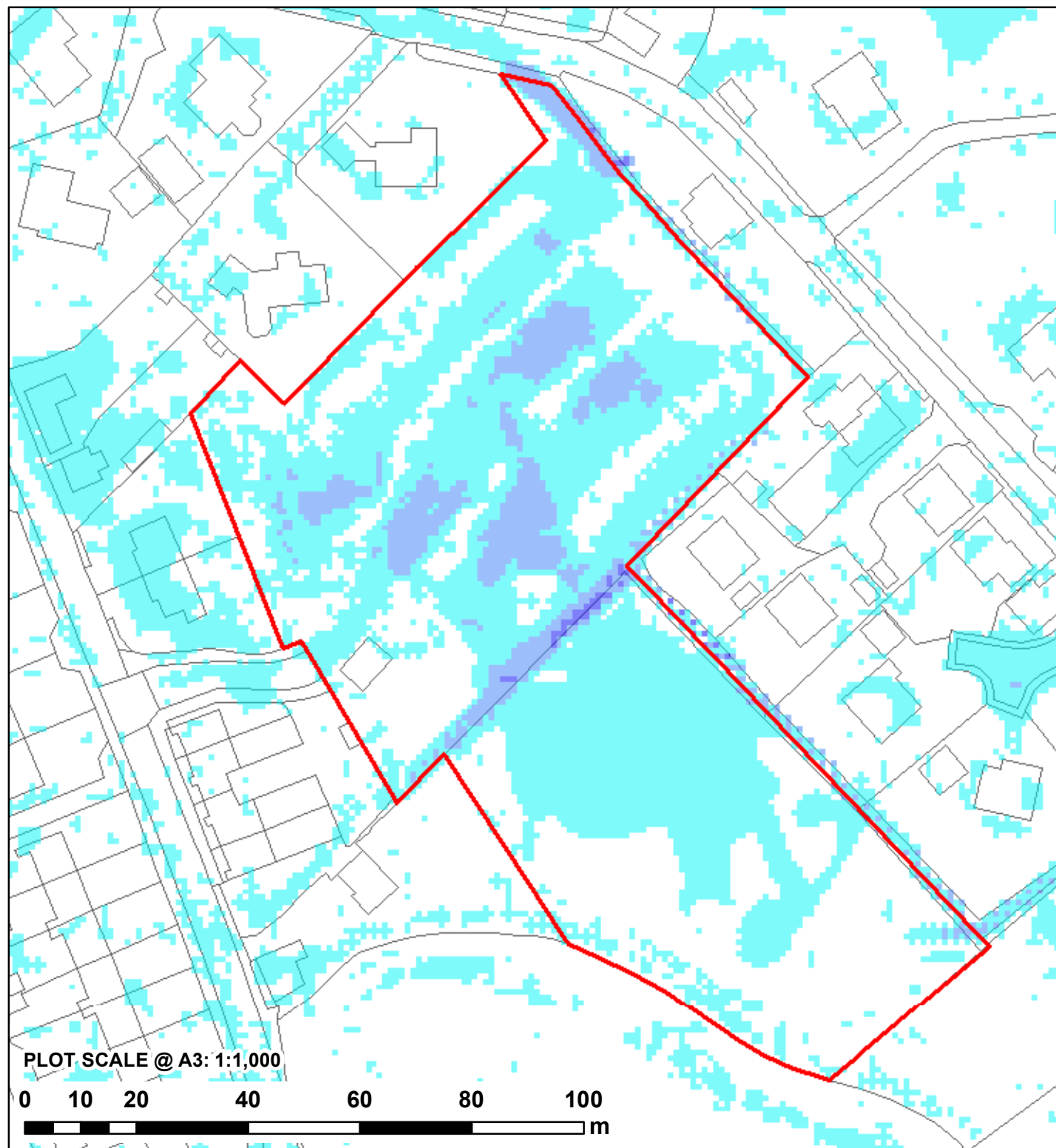
Yn falch o arwain y ffordd at ddyfodol gwell i Gymru trwy reoli'r amgylchedd ac adnoddau naturiol yn gynaliadwy.
Proud to be leading the way to a better future for Wales by managing the environment and natural resources sustainably.



Croesewir gohebiaeth yn Gymraeg a byddwn yn ymateb yn Gymraeg, heb i hynny arwain at oedi

Correspondence in Welsh is welcomed, and we will respond in Welsh without it leading to a delay

Appendix H Flood Mapping



NOTES:
 1) ALL DIMENSIONS ARE IN METRES AND ALL LEVELS IN METRES ABOVE ORDNANCE DATUM UNLESS STATED OTHERWISE
 2) MAXIMUM FLOOD DEPTHS BELOW 10mm ARE DEEMED NEGLIGIBLE AND ARE NOT SHOWN

LEGEND

Site Boundary

Model Extent

Maximum Flood Depth (m)

0 - 0.3

0.3 - 0.6

0.6 - 1.2

1.2 - 2.4

> 2.4

CLIENT:

TAYLOR REED HOMES LTD

waterco

www.waterco.co.uk

SCHEME:

MAIN STREET, BETTISFIELD

PLOT TITLE:

MAXIMUM FLOOD DEPTH
 5% AEP PLUVIAL EVENT
 EXISTING SITE LAYOUT
 NORMAL FLOW CONDITIONS

PLOT STATUS:

FINAL

DATE:

29/01/2020

DRAWN: VJ

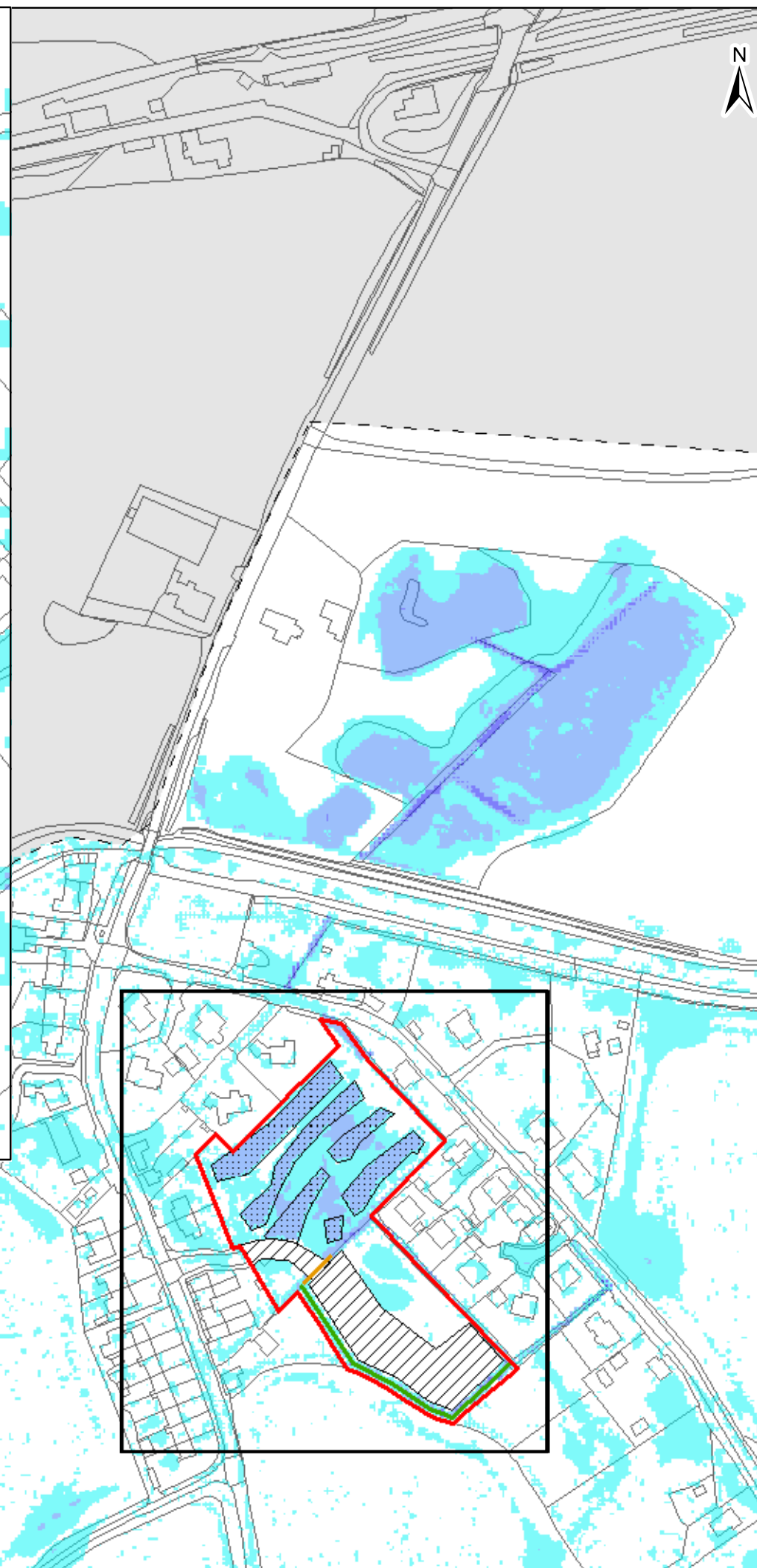
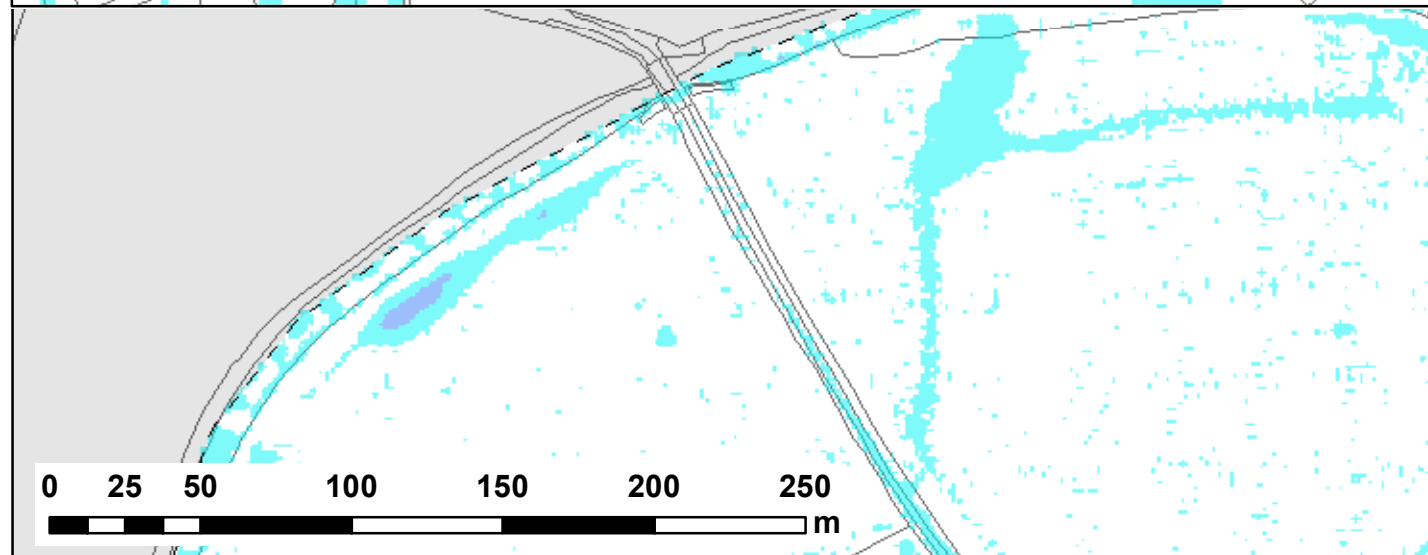
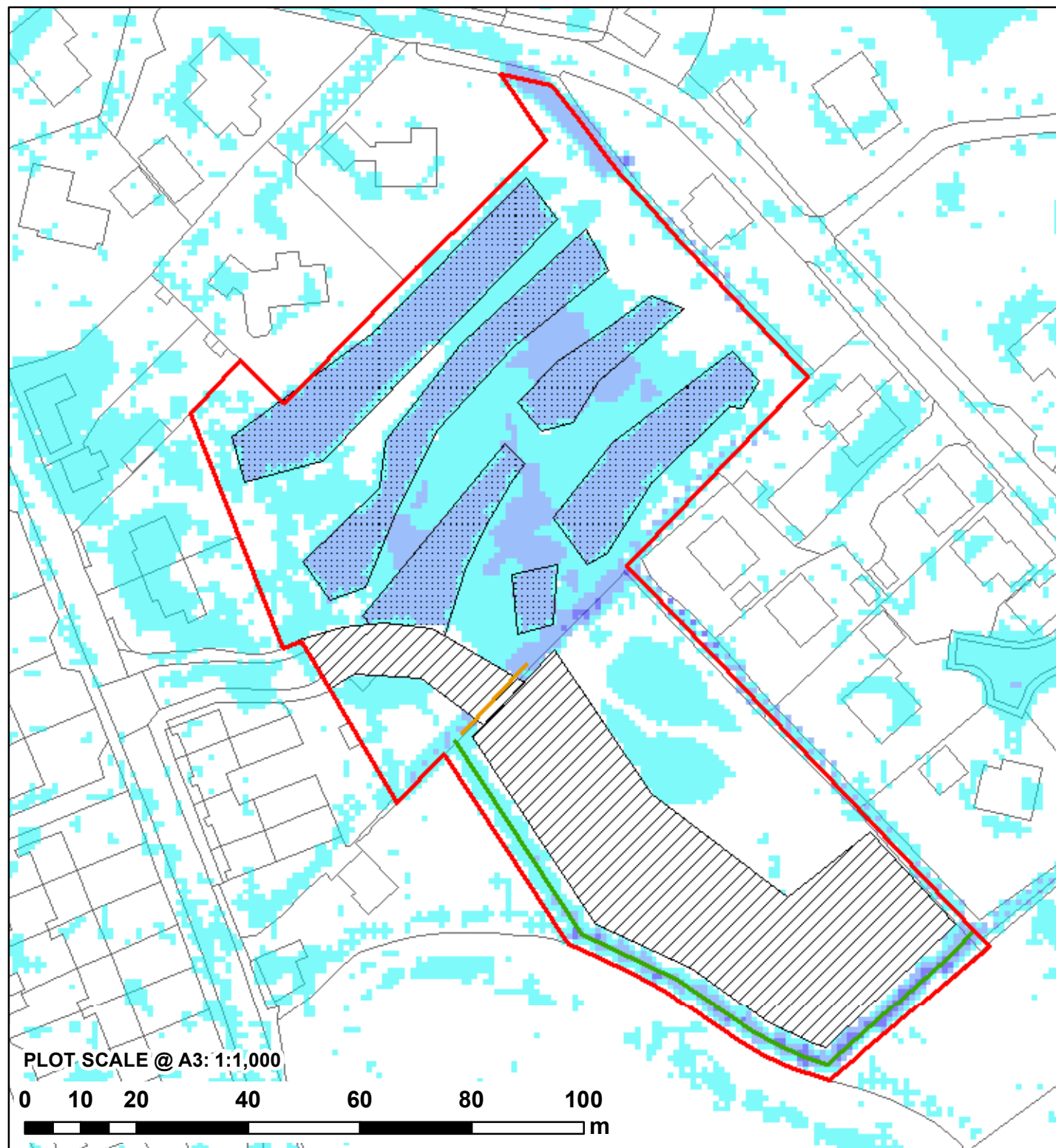
CHECKED: DH

APPROVED: AR

PLOT SCALE @ A3: 1:2,500 (UNLESS STATED OTHERWISE)

PLOT NAME: 12296-BETT_Q20_EXG_NFC_d_Max

REV: -



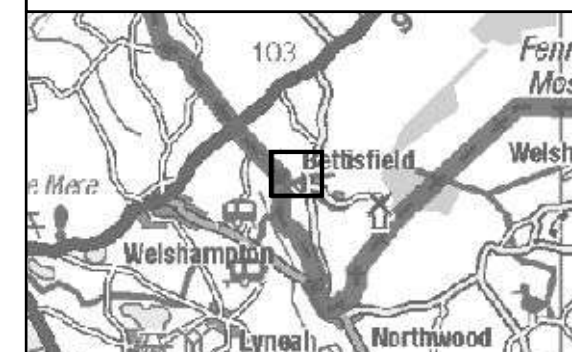
NOTES:
1) ALL DIMENSIONS ARE IN METRES AND ALL LEVELS IN METRES ABOVE ORDNANCE DATUM UNLESS STATED OTHERWISE
2) MAXIMUM FLOOD DEPTHS BELOW 10mm ARE DEEMED NEGLIGIBLE AND ARE NOT SHOWN

LEGEND

- Site Boundary
- Proposed Flood Relief Culvert
- Proposed Ditch
- Proposed Platform
- Proposed Site Lowering
- Model Extent

Maximum Flood Depth (m)

- 0 - 0.3
- 0.3 - 0.6
- 0.6 - 1.2
- 1.2 - 2.4
- > 2.4



CLIENT:

TAYLOR REED HOMES LTD



www.waterco.co.uk

SCHEME:

**MAIN STREET,
BETTISFIELD**

PLOT TITLE:

**MAXIMUM FLOOD DEPTH
5% AEP PLUVIAL EVENT
CONCEPT SITE LAYOUT (DEV)
NORMAL FLOW CONDITIONS**

PLOT STATUS:

FINAL

DATE:

29/01/2020

DRAWN:

VJ

CHECKED:

DH

APPROVED:

AR

PLOT SCALE @ A3:

1:2,500

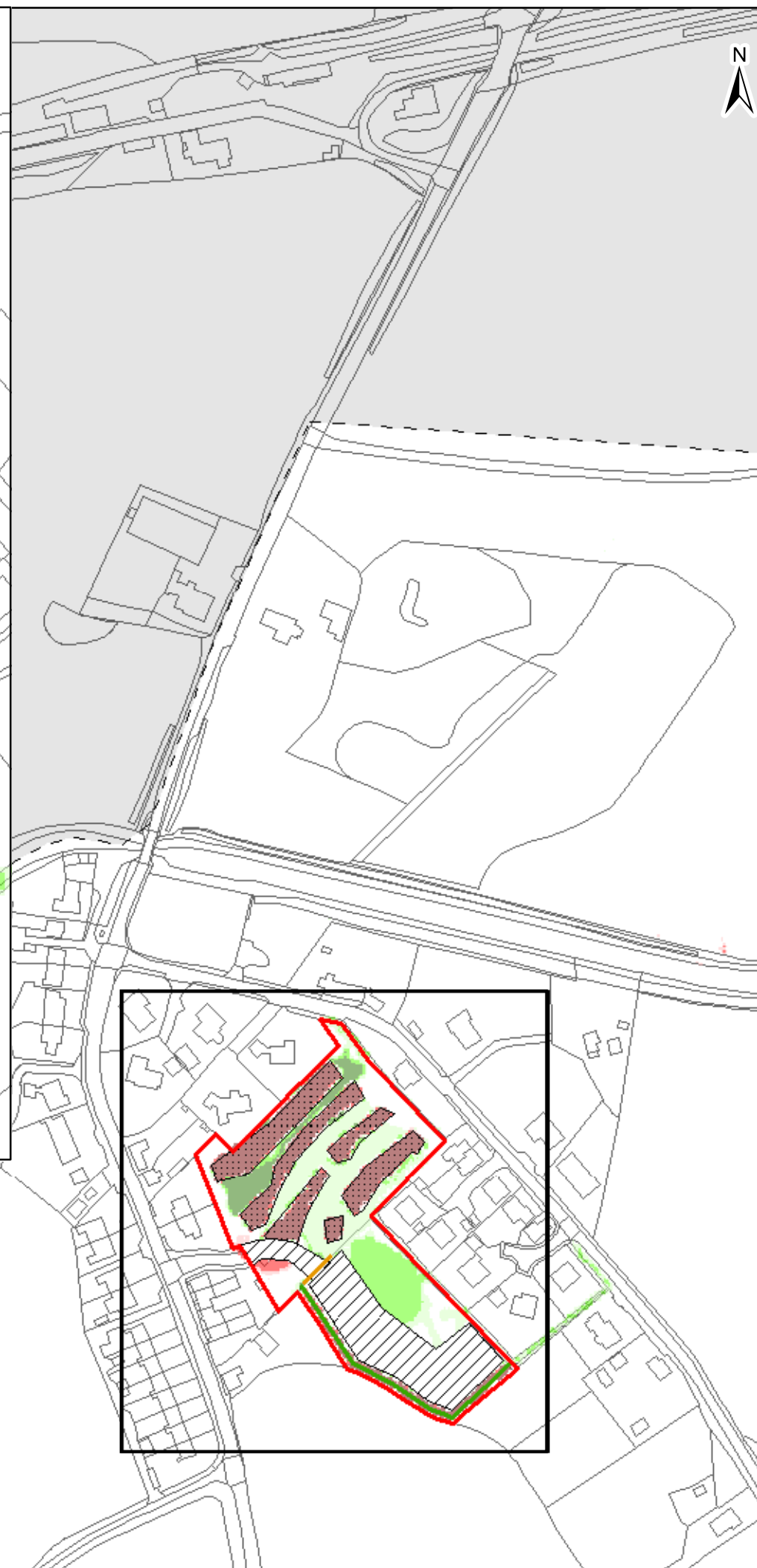
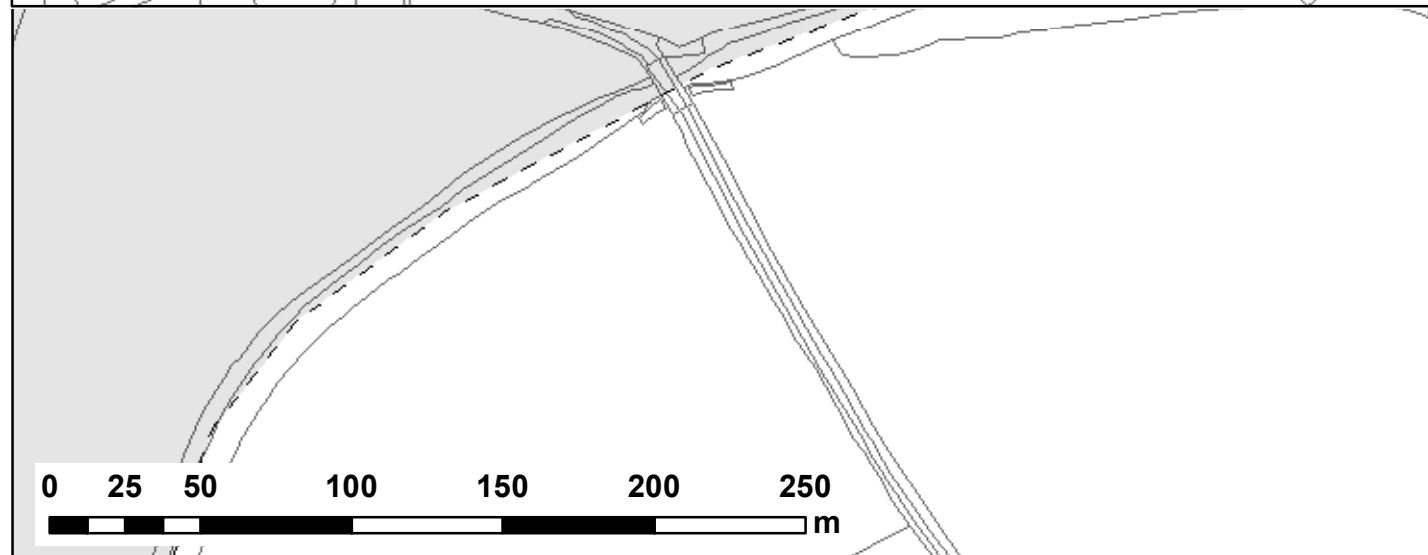
(UNLESS STATED OTHERWISE)

PLOT NAME:

12296-BETT_Q20_DEV3_NFC_d_Max

REV:

-



NOTES:
 1) ALL DIMENSIONS ARE IN METRES AND ALL LEVELS IN METRES ABOVE ORDNANCE DATUM UNLESS STATED OTHERWISE
 2) MAXIMUM FLOOD DEPTHS BELOW 10mm ARE DEEMED NEGLIGIBLE AND ARE NOT SHOWN

LEGEND

- Site Boundary
- Proposed Flood Relief Culvert
- Proposed Ditch
- Proposed Platform
- Proposed Site Lowering
- Model Extent

Maximum Depth Variation

- > +100mm
- +50mm to +100mm
- +5mm to +50mm
- No Change (+/-5mm)
- 5mm to -50mm
- 50mm to -100mm
- > -100mm

CLIENT:
 TAYLOR REED HOMES LTD

waterco
 www.waterco.co.uk

SCHEME:
 MAIN STREET,
 BETTISFIELD

PLOT TITLE:
 MAXIMUM DEPTH DIFFERNECE
 5% AEP PLUVIAL EVENT
 DEV-EXG
 NORMAL FLOW CONDITIONS

PLOT STATUS:
 FINAL

DATE:
 29/01/2020

DRAWN:
 VJ

CHECKED:
 DH

APPROVED:
 AR

PLOT SCALE @ A3:
 1:2,500
 (UNLESS STATED OTHERWISE)

PLOT NAME:
 12296-BETT_Q20_DEV3-EXG_NFC_D_DIFF

REV:
 -